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VARIABLES AFFECTING THE PERFORMANCE OF JET FUEL FILTER-SEPARATORS

Robert K. Johnston
Robert D. Brown
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Frank Fernandez, Jr.

Southwest Research Institute

TECHNICAL REPORT AFAPL-TR-70-36

June 1970

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FOREWORD

This report was prepared by Southwest Research Institute, San Antonio, Texas, under Contract F33615-69-C-1166. The contract was initiated under Project No. 3048. The work was performed by contractor's personnel using Air Force facilities at Wright-Patterson AFB. The program was administered by the Fuel Branch of the Fuels, Lubrication, and Hazards Division, Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio. The Air Force project engineer during the period reported was Mr. Paul C. Linder (APFF).

This is the Final Technical Report under subject contract, covering work performed between 2 December 1968 and 31 December 1969, including experimental work and also the analysis of data collected under previous contracts. This report was submitted by the authors on 30 April 1970. Contractor's identifying numbers are Project No. 12-2496 and Report No. RS-544.

Many of the items compared in this report were commercial items that were not developed or manufactured to withstand the tests to which they were subjected, or to operate as applied during this study. Any failure to meet the objectives of this study is no reflection on any of the commercial items discussed herein or on any manufacturer.

This technical report has been reviewed and is approved.

Arthur V. Churchill

Arthur V. Churchill, Chief
Fuel Branch
Fuels, Lubrication, and Hazards Division
Air Force Aero Propuision Laboratory

ABSTRACT

Results are presented from the final year of a 5-year program in research and development in hydrocarbon fuel handling and contaminant control, along with a statistical analysis of results from earlier tests performed to develop procedures for evaluating filter-separator elements, fuels, and fuel additives. The program included a large number of tests in a single-element filter-separator test rig and a variety of small-scale studies. A small coalescer device was developed and operated to study the role of filter-media parameters in removal of free water from fuel. In the water separometer (WSIM) test, variability in coalescer disks was shown to be one of the primary sources of poor repeatability; no significant improvement could be made by the use of controlled washing or disk-conditioning procedures, but the use of fine media offered some promise for improvement. In a small-scale investigation of low-temperature plugging of filter media, it was found that addition of fuel system icing inhibitor (FSII) increased the plugging rates, and that elimination of the glycerol component of the FSII did not solve the problem completely. In an investigation of analytical methods for the FSII content of fuels, it was found that the standard refractometer method (Method 5340 in Fed Std 791a) gives results about 10% below the true values and that this systematic error can be eliminated by using a different method of calibration. Large-scale tests on a Static Charge Reducer demonstrated its effectiveness on several fuel blends at 300- and 600-gpm flow rates. The antistatic additive ASA-3 was effective in minimizing charge buildup in uninhibited JP-5 fuel but was less effective in these tests when the fuel contained a corrosion inhibitor.

Distribution of this Abstract is unlimited.

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LIST OF ABBREVIATIONS

Al/SS	Filter-separator test loop, 15-60 gpm, aluminum and stainless steel construction
AC	Standard test dust ("Arizona road dust"), coarse or fine grade
AEL	Method and apparatus for determination of free water content of fuels, developed by the Aeronautical Engine Laboratory (Navy)
AFA	DuPont AFA-1 fuel corrosion inhibitor
AIA	Anti-icing additive (same as FSII)
API	Gravity, arbitrary scale (American Petroleum Institute)
ASA	Antistatic additive ASA-3 (Shell)
ASTM	American Society for Testing and Materials (designation for test procedure)
Bn	Bendix 04580004 filter-separator elements
Bw	Bowser-Briggs A-1389B filter-separator elements
CAC	Coarse AC dust
CT	Clay-treated
EDS	Na-Sul EDS fuel corrosion inhibitor (Vanderbilt)
EGME	Ethylene glycol monomethyl ether (2-methoxyethanol); major constituent of FSII
EP	End point (of distillation)
FAC	Fine AC dust
FI	Filters Inc. I-4208 filter-separator elements
Fr	Fram CC-S11B filter-separator elements
FSII	Fuel system icing inhibitor, MIL-I-27686D, consisting of EGME with minor amount of glycerol
FTMS	Federal Test Method Standard
GIO	Ground iron ore
IBP	Initial boiling point (of distillation)
IFT	Interfacial tension
K-F	Karl Fischer method for determination of total water content
Lubr	Lubrizol 541 fuel corrosion inhibitor

LIST OF ABBREVIATIONS (Cont'd)

NA-1	Sodium naphthenate, fuel-soluble, medium molecular weight
NC-2	Sodium naphthenate, fuel-soluble, high molecular weight
PtCR	Petronate CR (Sonneborn) sodium sulfonate
PTFE	Poly (tetrafluoroethylene)
PtL	Petronate L (Sonneborn) sodium sulfonate
RIO	Red iron oxide (standard test dust)
RP	DuPont RP-2 fuel corrosion inhibitor
RVP	Reid vapor pressure
SCR	Static Charge Reducer (A. O. Smith)
SD	Standard deviation
Snt	Santolene C (Monsanto) fuel corrosion inhibitor
ST	Surface tension
Tol	Tolad 244 (Petrolite) fuel corrosion inhibitor
Tot	Totamitor (Bowser), fuel turbidity meter
Uni	Unicor M (Universal Oil Products) fuel corrosion inhibitor
WSIM	Water Separometer Index Modified, ASTM D 2550

SECTION I

INTRODUCTION

This report covers the final year of a 5-year program in research and development in hydrocarbon fuel handling and contaminant control, plus a more complete analysis of earlier tests concerned with development of suitable test procedures for evaluating filter-separator elements, fuels, and fuel additives.

Other phases of this work have been concerned with development of a small-scale device for studying the role of various filter-media parameters in the coalescence of free water from fuels, the problem of media plugging at low temperatures, the effects of various factors on water separometer test results, the determination of fuel system icing inhibitor concentration by the refractometer method, the effectiveness of a static charge reducer apparatus and an antistatic additive, and the feasibility of determining solids contents of fuel and water by means of silver membrane filters.

A number of related subjects have been studied both in the earlier years of this program and during the final year reported here. These studies are described in earlier reports[(1-7)*].

Appended to this report are complete data from 93 single-element filter separator tests. Including earlier reports, complete data from 330 tests have been reported.

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*Raised numbers in parentheses refer to the List of References at the conclusion of this report.

SECTION II

TEST FACILITY AND EQUIPMENT

1. Test Loop

The test loop used in the experiments considered herein has been described in detail in a previous report.(3) The primary objective in the design of this loop was to ensure its adaptability to a wide variety of test conditions in experiments with single elements or with filter-separator assemblies. Aluminum and stainless steel were the principal materials of construction; no copper alloys nor carbon steels were used for fuel-wetted parts. For purposes of identification in this report, this facility is termed the Al/SS loop.

A simplified flow diagram of the loop is shown in Figure 1. For the work reported herein, fuel was pumped into one of the two tanks shown in the diagram and recirculated through the test system and back to the same tank. The volume of fuel used in each test was 600 gal, and the flow rate for most tests was 20 gpm.

The water-injection system is independent of the water-main pressure and can be used with water of any desired composition. In the majority of tests considered herein, filtered water from the mains was used.

Ahead of the water-injection point, dry fuel is drawn to feed the solids-injection system, which is shown schematically in Figure 2. Dry-solids injection was used in most of the work reported herein, but premixed slurry was used in a few tests.

In order to give the reader a general idea of the efficiency of the dirt feeder used in the loop tests reported herein, the following table was prepared:

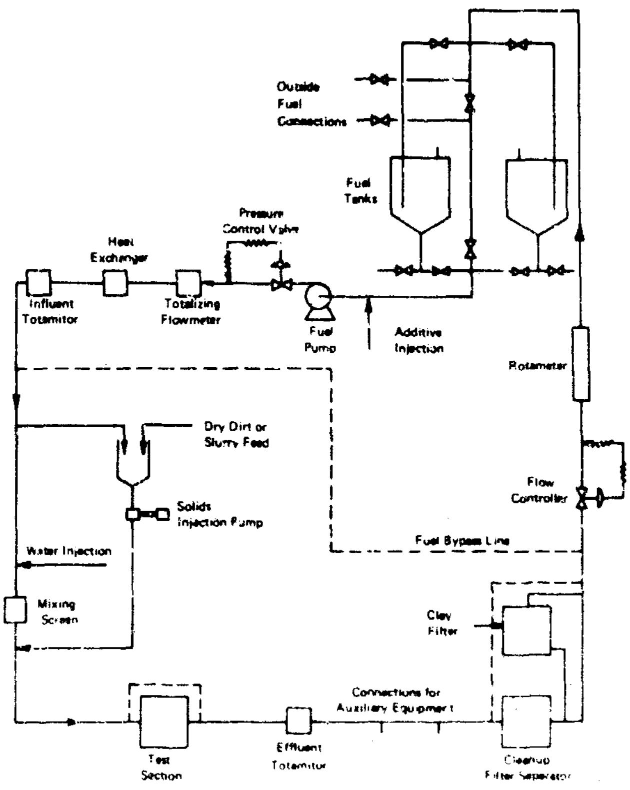

FIGURE 1. SIMPLIFIED FLOW DIAGRAM OF Al/SS LOOP

Type of solids	Number of tests	% accuracy of delivery
Coarse AC dust	191	93.4
Fine AC dust	48	91.6
Red iron oxide (I-116)	6	104.9
Red iron oxide (R-9998)	7	70.1
Ground iron ore (B-00985)	8	92.2
Black iron oxide ("N")	2	101.4
50% fine, 50% coarse AC dust	10	93.4

Percent accuracy of delivery with the different contaminants was calculated by determining the element weight gain due to solid contaminant retention during a single-element loop test (dirt recovered), dividing that figure by the nominal dirt delivered into influent fuel during the test, then multiplying by 100.

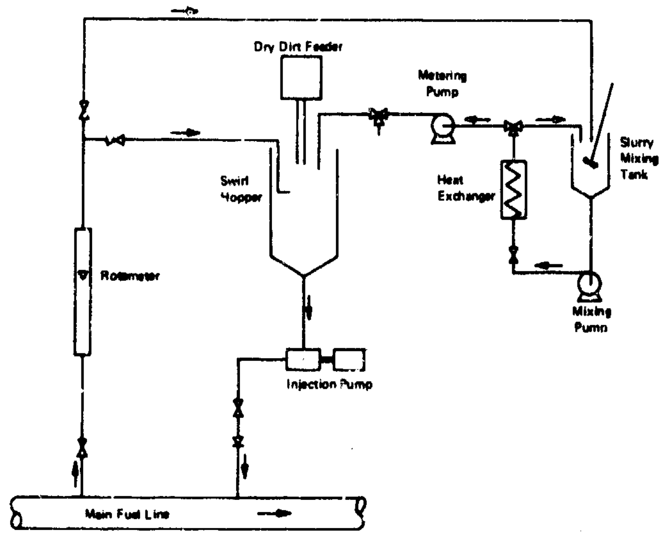

FIGURE 2. SOLID-CONTAMINANT SYSTEM

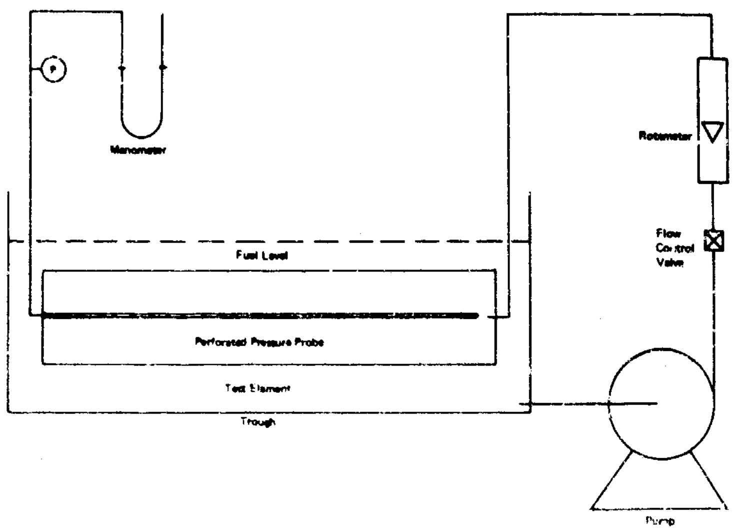

FIGURE 3. PRESSURE-CHECK TROUGH

Essentially all of the work reported herein was performed with an 8-in. aluminum housing equipped with a single military-standard element and a double-wall PTFE-coated screen canister. Brief studies were made with a transparent housing designed for observation of flow patterns. Both of these housings are described in detail in Reference 3.

The clay filter shown in Figure 1 was installed during the latter part of the program. It is a Peco Series 34, Model 34-3-736D, rated at 42 gpm, with three Peco No. PC 736-D clay canisters.

2. Pressure-Check Trough

During the latter portion of the program, the fuel flow resistance of each test element was measured for correlative purposes. This was done immediately before each test by mounting the element in an open trough containing fresh, uninhibited JP-5 fuel and measuring the pressure loss (ΔP) while pumping fuel through the element at 20 gpm. This apparatus is shown schematically in Figure 3. The pressure probe was designed to eliminate any velocity-head effects. The fuel temperature was not controlled, but was generally 60 to 70°F or, in extreme cases, 55 to 75°F. This apparatus was used to check most of the element starting with Test 220. Originally, a 15-in. mercury manometer was used to measure the ΔP, positioning the manometer to eliminate fuel-leg correction. After Test 298, a pressure gage was used. All element ΔP values in this report are expressed in psi.

Such extra handling of the element prior to test is somewhat undesirable because of the possibilities of physical damage and of changing the element's performance characteristics. Earlier, an attempt had been made to obtain element ΔP values by measurements on the test housing and canister, with and without the element. As described later in this report, the flow characteristics in the housing are altered so drastically by the presence of the element that no valid measure of element ΔP could be obtained by this method of differences.

3. Small-Scale Equipment

Bench-scale and laboratory equipment used in this program are described in later sections of this report, along with the discussions of results obtained with such equipment.

SECTION III

TEST MATERIALS

1. Test Fuel

Test fuels for this work were JP-4 and JP-5, supplied without additives. These fuels were held in Air Force storage facilities for this and other programs. Batches of 12 to 25,000 gal of fuel were transferred from Air Force storage, by means of refueling trucks, to storage tanks located adjacent to the test facility. Each such transfer represented a "batch" of fuel as defined for this program. Fuel batches were used in Al/SS loop tests as follows:

Batch No.	Type	Test No.
14	JP-4	48-62
15	JP-5	63-76
16	JP-5	77-83
17	JP-5	84-99
18	JP-5	100-128
19	JP-5	129-150
20	JP-5	151-175
21	JP-5	176-199
22	JP-5	200-211
*	JP-4	212-219
23	JP-5	220-258B
24	JP-5	259A-313
25	JP-5	314-329

*From Area B, TK 12, received 6 February 67.

Inspection data for these fuels are presented in Table 1, and military specifications for JP-4 and JP-5 are given in Table 2.

2. Fuel Additives

Fuel corrosion inhibitors used in this work are listed below, along with the abbreviated designations used in tables and figures of this report:

Snt	Santolene C (Monsanto)
AFA	AFA-1 (duPont)
RP	Rust Preventive-2 (duPont)
Uni	Unicor M (Universal Oil Products)
EDS	Na-Sul EDS (Vanderbilt)
Tol	Tolad 244 (Petrolite)
Lubr	Lubrizol 541 (Lubrizol)

All of these inhibitors except the Na-Sul EDS are qualified materials under MIL-I-25017B. The Na-Sul EDS had been qualified under an earlier version of the inhibitor specification, before any close restrictions had been placed on emulsification behavior.

The icing inhibitor used in this work, designated as AIA (anti-icing additive) or FSII (fuel system icing inhibitor), was obtained from Dow Chemical Company and conformed to MIL-I-27686D. The specified composition of this material was 99.6% 2-methoxyethanol (ethylene glycol monomethyl ether) and 0.4% glycerol.

TABLE 1. INSPECTION TEST RESULTS ON UNINHIBITED FUELS

SwRI batch no.	Sample from	Date	API Grav	Distillation, °F IBP-10%-20%-50%-90%-EP	Gum, mg/100 ml Exist	Gum, mg/100 ml Poten	Flash, °F	RVP, psi	WSIM
	JP-4 Fuel								
---	Ashland*	1/25/67	55.2	126-192-224-300-420-506	0.6	1.8	---	3.0	96
14	Tank	3/16/67	---	122-188-220-299-423-499	0.4	---	---	2.9	---
	JP-5 Fuel								
15	Truck	4/10/67	---	353-380-394-421-468-496	0.2	0.2	---	---	---
15	Tank 1	4/21/67	42.7	340-377-389-415-460-494	0.6	0.6	134	---	99
15	Tank 2	4/21/67	42.7	346-378-389-416-458-488	0.6	0.6	137	---	---
15	Tank 2	5/31/67	---	353-382-395-422-465-490	1.0	1.0	135	---	88
16	Tank 1	5/31/67	---	356-380-396-421-462-491	1.0	1.0	134	---	---
16	Tank 2	5/31/67	---	354-383-396-423-464-490	1.0	1.0	136	---	89
17	Tank 1	7/6/67	42.7	348-383-394-420-462-491	0.4	0.6	134	---	72
17	Tank 2	7/6/67	42.7	351-382-396-422-466-489	0.4	0.8	134	---	87
18	Tank 1	8/14/67	42.5	353-382-394-421-465-494	1.2	1.4	136	---	---
18	Tank 2	8/14/67	42.5	358-378-397-421-466-498	1.4	1.4	138	---	---
19	Tank 1	No data except WSIM							94
20	Tank 1	10/5/67	42.6	357-385-395-420-467-500	0.2	0.8	137	---	95
20	Tank 2	10/5/67	42.6	357-384-395-422-468-499	0.6	1.2	138	---	77
---	Ashland*	10/6/67	42.0	380-398-402-412-446-490	0.6	2.9	154	---	98
21	Tank 1	1/16/68	41.1	372-399------425-456-484	1.0	1.0	146	---	98
21	Tank 2	1/16/68	41.1	372-398------424-454-494	0.8	1.0	147	---	94
22	Tank 1	3/18/68	41.2	366-396-405-422-453-491	0.2	---	148	---	89
22	Tank 2	3/18/68	41.1	380-401-408-426-457-498	0.4	---	148	---	---
23	Tank 1	6/28/68	41.8	362-386-394-415-458-482	0.0	1.0	143	---	92
23	Tank 2	6/28/68	41.7	364-384-390-412-456-490	0.0	1.0	144	---	95
23	Tank 1	7/22/68	41.8	356-382-390-412-457-481	1.0	1.0	143	---	87
23	Tank 1	8/16/68	41.9	346-384-394-414-457-482	---	---		---	78
23	Tank 2	11/18/68	41.8	369-388-395-415-458-495	0.0	0.6	145	---	75
23	Tank 2	12/3/68	41.7	372-388-395 417-458-493	0.2	0.6	144	---	---
24	Tank 1	6/10/69	41.7	368-384-394-415-458-498	2.2	2.2	142	---	92
24	Tank 2	6/10/69	41.8	367-386-394-414-457-492	0.4	1.0	144	---	98
25	Tank 1	7/7/69	42.2	356-388-396-416-460-491	0.2	0.4	129	---	91
25	Tank 2	7/7/69	42.0	363-388-395-414-458-495	0.2	0.6	142	---	92

*Source inspections by Ashland. All other inspections by AF laboratories.

TABLE 2. MILITARY SPECIFICATIONS FOR JP-4 AND JP-5

	MIL-T-5624G, 5 Nov 65*	
	JP-4	JP-5
Gravity, API/60	45-57	36-48
Distillation: 20%, °F, max	290	—
50%, °F, max	370	—
90%, °F, max	470	—
EP, °F, max	—	550
Residue, %, max	1.5	1.5
Loss, %, max	1.5	1.5
Existent gum, mg/100 ml, max	7	7
Potential residue, mg/100 ml, max	14	14
Sulfur, %, max	0.4	0.4
Mercaptan sulfur, %, max	0.001	0.001
Reid vapor pressure, psi	2.0-3.0	—
Freezing point, °F, max	−72	−51
Heat of combustion, Btu/lb, min	18400	18300
Aniline-gravity product, min	5250	4500
Viscosity, cs at −30°F, max	—	16.5
Aromatics, vol %, max	25	25
Olefins, vol %, max	5	5
Smoke point, mm, min	—	19
Luminometer no., min	60	50
Explosiveness, %, max	—	50
Flash point, °F, min	—	140
Smoke volatility index, min	52.0	—
Copper corrosion, ASTM, max	No. 1	No. 1
WSIM, min	85†	85†
Water reaction rating, max	1-b	—
Thermal stability:		
Filter ΔP, in. Hg, max	3.0	3.0
Preheater deposit color	<3	<3
Particulate matter, mg/gal, max		
F.O.B. origin deliveries	4	—
F.O.B. destination deliveries	8	—
FSII content, vol %	0.10-0.15	—

*Written to cover fuels without corrosion inhibitor. Subsequent reinstatement of corrosion inhibitor in JP-4 was covered by Amendment 1, 21 Nov 66.
†For JP-4, minimum WSIM was dropped to 70 by Amendment 1 at the same time corrosion inhibitors were reinstated in that fuel. Minimum WSIM remained at 85 for JP-5 (without corrosion inhibitor).

Five other additives used in this group of tests were as follows:

ASA	Antistatic additive ASA-3 (Shell)
PtL	Petronate L sodium sulfonate (Witco)
PtCR	Petronate CR sodium sulfonate (Witco)
NC-2	Sodium naphthenate from 415 mol. wt acids, 25% active ingredient
NA-1	Sodium naphthenate from 310 mol. wt acids, 25% active ingredient

3. Injection Waters

The contaminant-water used in these tests consisted either of filtered tap water or synthetic blends of various compositions. The tap water available from the mains at Wright-Patterson AFB is hard well-water with no treatment except chlorination to 0.4 ppm gas injection. Total hardness is about 380 ppm, and pH is about 7.6. It has been used for a considerable amount of single-element testing and has been found to be quite consistent in pH and surface tension. It appears quite suitable for use in filter-separator testing, so long as a suitable filter is installed in the water-injection system to guarantee a low content of insoluble materials.

The principal synthetic water composition used in this work was originally designated "Standard Water No. 1," but subsequently was designated "Type B" since it is a close match for the Type B medium-hardness water frequently cited in handbooks as typical of Great Lakes water supplies. This synthetic water was blended from distilled water and reagent-grade chemicals to the following composition (mg/liter):

Actual ingredients blended		Ionic concentrations	
$NaHCO_3$	164	Ca	36
$CaCl_2 \cdot 2H_2O$	132	Mg	8.1
$MgSO_4 \cdot 7H_2O$	82	Na	45
		Cl	64
		SO_4	32
		HCO_3	119

The filtered tap water or the Type B synthetic water was used in most of the Al/SS loop tests reported herein. Table 3 gives injection water quality parameters as measured in the loop tests.

Other synthetic waters were blended for special tests, using distilled water or type B blend as the base for investigating the effects of water composition and properties on element performance. These waters were as follows:

pH 5 (distilled + 115 mg/ℓ NaCl + HCl)

pH 7 (distilled + 115 mg/ℓ NaCl + NaOH)

pH 10 (distilled + 115 mg/ℓ NaCl + NaOH)

pH 9.5 (Type B + NaOH)

pH 9.5 (distilled + 164 mg/ℓ $NaHCO_3$ + NaOH)

Type B + NaCl to total Cl^- content of 932 mg/ℓ

65% Type B + 35% FSII

Distilled water

Distilled water contaminated with residues from a previous test (test 92) in which pH 9.5 water (Type B + NaOH) was used

The first series of waters to study pH effects was made from a sodium chloride solution adjusted to pH 5, 7, or 10 by adding minor amounts of HCl or NaOH, as required. The original ionic concentrations of the salt solution

TABLE 3. INJECTION WATER QUALITY PARAMETERS

Parameter statistics	Type of injection water		
	Filtered tap water	Type B synthetic water	65% Type B + 35% FSII
Surface tension, dyn/cm			
minimum	61	60*	47
maximum	74	74	47
mean	71.6	70.8	47
standard deviation	1.3	2.9	0
no. of measurements	218	37	3
Solids content, mg/ℓ			
minimum	0.0	0.0	0.0
maximum	2.4	1.3	2.0
mean	0.20	0.22	1.10
standard deviation	0.25	0.29	1.01
no. of measurements	218	38	3
pH			
minimum	7.1	7.9	6.8
maximum	8.1	8.5	7.7
mean	7.54	8.16	7.37
standard deviation	0.20	0.15	0.49
no. of measurements	218	38	3

*A value of 43 dyn/cm obtained in test 50 was not included in calculation of mean or standard deviation. It deviated from other values so much that it was judged to be erroneous.

were 45 mg/liter in sodium and 70 mg/liter in chloride; these were changed very little by the pH adjustments, the increases being less than 5 mg/liter in all cases. As would be expected, these waters had very little buffering capacity and could not "hold" their pH through the test cycle of mixing with fuel and separation. Hence, they did not provide satisfactory criteria of pH effects.

An attempt to prepare a buffered high-pH water by adding caustic to Type B water resulted in significant precipitation of solids and contamination of the water-injection system. The only satisfactory high-pH water that was prepared was the pH 9.5 water prepared from $NaHCO_3$ and NaOH; this was, in effect, a carbonate-bicarbonate mixture.

High-chloride water was prepared to simulate the chloride contents often found in water bottoms of fuel storage tanks. The blend of 35% FSII in Type B water was also intended to simulate field conditions, since any water that has been equilibrated with large amounts of JP-4 fuel will contain some 15 to 40% FSII, depending on fuel composition and temperature.

4. Solid Contaminants

The six solid contaminants used in this work were standard coarse AC dust, standard fine AC dust, standard fine red iron oxide (Fisher I-116), a coarser red iron oxide (Pfizer R-9998), ground iron ore (Pfizer B00985), and magnetic black iron oxide (Chemical Commerce Co N). The first three of these materials are used regularly in filter-separator specification tests. The R-9998 red iron oxide was used in seven tests, the ground iron ore was used in eight tests, and the black iron oxide was used in two tests.

The AC dusts are siliceous "Arizona road dust" that has been collected and standardized for use in testing air cleaners and filters. The coarse grade has a broad range of particle size, with appreciable amounts in the 80-200 and below 5 μ fractions. The fine grade is prepared from the coarse by removing the larger particles.

Both of the red iron oxides are high-purity materials produced by calcination of ferrous sulfate. Both are much finer in particle size than the AC dusts and the Fisher I-116 is the finer of the two.

Complete specifications on particle size distribution of the solids are given in Table 4.

TABLE 4. PARTICLE SIZE DISTRIBUTION OF TEST DUSTS

	Standard AC test dust		Red iron oxide		Ground iron ore Pfizer B-00985	Black iron oxide Chemical Commerce Co "N" magnetic
	Coarse	Fine	Pfizer R-9998	Fisher I-116*		
Weight % below 200μ	100	---	---	---	100	100
80	91	100	---	---	99.9	99
40	61	91	---	---	76.9	78.2
20	38	73	---	---	62.6	54.5
15	---	---	100	100	59.3	43.5
10	24	57	99.3	100	53.0	29.0
7.5	---	---	98.3	99.7	45.6	17.6
5	12	39	84.9	98.9	32.1	8.0
4	---	---	74.5	98.2	25.6	4.5
3	8†	21†	25.2	97.9	17.4	1.7
2	5†	11†	7.3	97.1	8.0	---
1	---	---	5.6	94.1	0.2	---
0.5	---	---	4.9	77.7	---	---
0.25	---	---	---	47.8	---	---

*Same as Pfizer R-2199.
†Not specifications; values based on analysis of a few samples.

Other than these "test dusts," the only solid contaminants used were plug valve lubricants that were examined in three special tests. These were a MIL-G-6032 plug valve grease (Royal Lubricants Co) and Walworth No. 1 plug valve sealant.

5. Filter-Separator Elements

Filter-separator elements from four manufacturers were used in the tests reported herein. These elements are identified as to manufacturer and lot designation in Table 5, which also gives element weight statistics for each lot.

Although there is considerable difference in mean weight of elements from different manufacturers, this difference is of no practical significance with regard to element quality or performance, since the element designs are different. One statistic of interest in Table 5 is the standard deviation of element weights, which provides a measure of the conformity among elements of a given lot.

Seven different lots of Filters Inc elements were used. Weight variations among these lots may be of significance with regard to performance, since element construction appeared to be the same for all elements. Table 6 gives the level of significance of differences between the means of various pairs of lots. There is a significant difference in means between all lot pair-combinations except for Lots 440 and 440A. Later in the report (Section V), the extent of correlation between element weight and element performance will be discussed.

TABLE 5. FILTER-SEPARATOR ELEMENT DATA

Element manufacturer	Part no.	Designation	Test no.	Number of elements	Element weight values, g				SD % of mean
					Min	Max	Mean	SD	
Filters Inc	I-4208	Lot 286	48-83	37	623	764	657.5	26.2	4.0
Filters Inc	I-4208	Lot 428	84-90	6	625	678	661.8	18.9	2.9
Filters Inc	I-4208	Lot 440	91-150	58	590	680	641.2	23.1	3.6
Filters Inc	I-4208	Lot 440A	151-199	49	578	700	639.5	24.7	3.9
Filters Inc	I-4208	Lot 465	200-257,258A,276,278, 282,287,290,296,304,308	67	478	587	522.3	20.4	3.9
Filters Inc	I-4208	Lot 516	259A,260A,315-325	12	527	635	564.2	30.8	5.5
Filters Inc	I-4208	Govt Std	310-313	4	541	580	567.0	17.7	3.1
Fram	CC-S11B	Lot 14	261,264,265,268,273,280, 281,288,289,295,298,307	12	628	664	650.0	9.7	1.5
Bendix	04580004		262,266,267,269,274,279, 284,285,292,294,297,306	12	618	671	648.3	13.7	2.1
Bendix	04580004	No. 69 M 2814*	314,325,326	3	699	721	711.0	11.1	1.5
Bowser	A1389B		263,270,271,272,275,277, 283,286,291,293,305,309	12	617	691	635.5	19.8	3.1
Bowser	A1389B	Received used from Andrews AFB	299,301	---	---	---	---	---	---
Bowser	A1389B	†	327-329	3	642	674	654.3	17.2	2.6

*Special RIO elements.
†Special RIO elements no. A1389C were ordered: A1389B were received and tested.

TABLE 6. SIGNIFICANCE OF DIFFERENCES IN MEAN WEIGHTS OF FILTERS INC ELEMENTS OF DIFFERENT LOTS

Element lot	Probability of chance greater difference in mean weight for different lots, %					
	FI 286	FI 428	FI 440	FI 440A	FI 465	FI 516
FI 428	>50	---	---	---	---	---
FI 440	0.1-0.5	1-2.5	---	---	---	---
FI 440A	0.1-0.5	1-2.5	>50	---	---	---
FI 465	0.5-1.0	<0.1	<0.1	<0.1	---	---
FI 516	<0.1	<0.1	<0.1	<0.1	<0.1	---
FI GS	<0.1	<0.1	<0.1	<0.1	<0.1	>50

SECTION IV

TEST PROCEDURES

1. Loop Test Procedures

a. General

The test procedures discussed in this section are those used in single-element loop tests reported herein. Test procedures for other apparatus are discussed in Sections VII and VIII.

A total of 29 established test procedures was used in the single-element loop tests reported herein. Most of these procedures are directed toward the evaluation of inhibited fuels and are similar in concept to the inhibited-fuel test of MIL-F-8901A. The test procedures are outlined in the following pages and are listed for convenient reference in Table 7, which also shows the loop test numbers corresponding to each procedure number. In addition, 10 tests were run using special procedures. These vary greatly in schedule, contaminant, and purpose, and are described briefly in Table 8, and in detail in the remainder of this section.

The bulk of the work was performed using Procedures 10, 13-A, and 13-J. Procedure 10 is the same as the MIL-F-8901A inhibited-fuel test as to solid contaminant (coarse AC dust) and test schedule (60-min water injection only, then water and solids to 40 psi). Type B synthetic water was specified for Procedure 10, but some of the later tests were run with filtered tap water, after it had been found that the effects of water composition were of little significance. The sampling schedule and other details of Procedure 10 differ from those of the MIL-F-8901A inhibited-fuel test, as will be seen from the detailed outline to be presented.

Procedure 13-A represents a revision of Procedure 10 toward the direction of a more realistic sequence of operations. The solid contaminant is coarse AC dust (as before); the injection water is filtered tap water. The schedule requires injection of dust along with a very small amount of water (0.01% of fuel flow) until the element pressure drop reaches 20 psi. At this point, the dust injection is discontinued and the water injection rate is increased to 1% of fuel flow rate for a 15-min period. At this time, if the element pressure drop has not risen to 40 psi, water injection is continued at 1% and dust injection is restarted and continued to 40-psi pressure drop. This procedure is designed to eliminate the excessive water washing of the fuel and element that exists in MIL-F-8901A and Procedure 10 during the initial 1-hr period.

Procedure 13-J is identical to 13-A except for the use of fine AC dust as the solid contaminant.

Procedures 11 and 12 are MIL-F-8901A procedures, slightly modified, for a special series of evaluation tests.

The MIL-F-8901B tests employed are adaptations of the designated procedures for use in the Al/SS loop. In most cases, the only difference between the actual test procedure and the specified test procedure is the drawing of extra samples for analyses.

All of the other procedures represent modifications of 13-A that were investigated during the course of procedure development.

b. Procedure 10

Tests are run with a single military-standard coalescer element and double-wall canister mounted in an 8-in. aluminum housing. A fresh element is used for each test. The canister and housing are cleaned and rinsed thoroughly between tests.

TABLE 7. PROCEDURES USED IN LOOP TESTS

Procedure no.	Loop test nos.	Type of procedure
10	48-83,91-100,110,134 138,142,143,148	Similar to MIL-F-8901A inhibited-fuel test
11	84-86	MIL-F-8901A inhibited-fuel test
12	87-90	MIL-F-8901A red iron oxide slurry test
8901B	256(40 gpm),257(30 gpm)	Inhibited-fuel test
8901B	258-A,259-A	Media migration test
8901B	258-B,259-B	Dry red iron oxide test
8901B	260A	Water removal test
8901B	260B	Red iron oxide and water test
8901B	314,325-329	Modified inhibited-fuel test (Pfizer R9998 red iron oxide instead of AC dust)
13-A*	101,107,109,125,132, 133,136,137,140,141, 144,146,147,184-224, 230-255,261-298,304-313	"Dirt-first" loading with coarse AC dust and 0.01% water before 1% water injection
13-B	102	Initial dust without water
13-C	103	Final water rate, 3%
13-D	104	Extra 8 hr of fuel flow
13-E	105	Red iron oxide (I-116)
13-F	106	Dust injection rate, 25% normal
13-G	111	Fuel and water rates increased
13-H	112	Water into fuel pump suction
13-I	113,114	Fuel, 16 gpm; water to pump suction
13-J	115,126-131,135,139, 145,149-151,154,155, 157,159,161,162,170, 172,176-179,225-229	Fine AC dust
13-K	116	Fine AC dust; water 1% throughout
13-L	117	Same, extra 120 min fuel and water
13-M	124	Red iron oxide (R-9998)
13-N	152,153,156,158,160, 162-165,171,173	Fine AC dust at 50% normal rate
13-O	166-169,174,175,180-183	50/50 fine and coarse AC dust
13-P	315-322	Ground iron ore (Pfizer B00985)
13-Q	323-324	Black iron oxide (magnetic "N", Chemical Commerce Co)
14	108	4-hr cycles
14-A	118,119,121-123	4-hr cycles, fine AC dust
14-B	120	4-hr cycles, fine AC dust, loaded to 10 psi only

*Procedure 13-A and all subsequent procedures are of the "dirt-first" type in which the element is first loaded to 20 psi (or some specified pressure drop) with test dust, accompanied by 0.01% water. This is followed by a period of 1% water injection without dust injection, then by dust and water (1%) until the pressure drop reaches 40 psi. Subsequent procedures differ from 13-A only as specified.

TABLE 8. SPECIAL LOOP TESTS

Test no.	Element*	Test fuel contaminants	Purpose of test
203A	1	Water	To expose element to fuel and water for subsequent dryout and retest.
204	2	Water, coarse AC dust	To evaluate performance of an element which had been previously subjected to fuel and water and then allowed to dry.
299	3	Water	To determine if element had any water coalescing capability.
300A	4	Water, plug valve grease†	To determine the effect of plug valve grease on element performance.
300B	2	Water	To determine coalescing capability of element which had previously been exposed to plug valve grease.
300C	2	Water	To determine coalescing capability of element which had previously been exposed to plug valve grease.
300D	2	Water	To determine coalescing capability of element which had previously been exposed to plug valve grease.
301	5	Water, plug valve sealant‡	To determine the effect of plug valve sealant on element performance.
302	4	Water, plug valve sealant‡	To determine the effect of plug valve sealant on element performance.
303A	4	Water, coarse AC dust, glycerol	To determine the effect of glycerol and coarse AC dust on element performance.
303B	2	Water, coarse AC dust, glycerol	To determine the effect of glycerol and coarse AC dust on element performance.

*Element identification:
1. Filters Inc, I-4208, lot 465.
2. Same element that was used in previous test.
3. Used Bowser element from Andrews AFB (part no. A 1389 B).
4. New Bowser element (part no. A1389 B).
5. Used Bowser element from Andrews AFB (A 1389 B), which had been soaked in isopropanol for over 24 hr.

†Available from Royal Lubricants Co. conformed to MIL-G-6032.
‡Identified as Walworth No. 1.

Standard test conditions are:

Fuel flow rate	20 gpm
Fuel supply pressure	70 psi
Fuel temperature entering test section	80°F (75°F in early tests)

Standard contaminants are coarse AC dust and Type B synthetic water*. The test schedule starts with a 15-min "pre-test" period with fuel flow but no contaminant injection. The start of the test proper (zero time) is the end of this pre-test period, at which time the contaminants are injected according to the following schedule:

0 to 60 min	Water 0.2 gpm, no solids
Remainder (to 40 psi)	Water 0.2 gpm, solids 5.72 g/min

The solids injection rate corresponds to a concentration of 0.286 g/gal in the fuel. At this injection rate, the element is loaded to its nominal dirt-holding capacity of 200 g in 35 min.

Either fresh base fuel or fuel from the preceding test may be used. The following step-by-step test procedure is used with fresh base fuel, starting with a clean system:

Weigh a new coalescer element to the nearest gram, and check for integrity in the coalescence tank, using uninhibited base fuel. Then install the element in the single-element aluminum housing, along with a double-wall canister:

Note. The element may be installed at any time prior to the start of the pre-test period.

Pump 600 ± 50 gal of clean base fuel through a suitable cleanup filter-separator (outside the loop) and into one of the loop fuel tanks. Determine the amount actually charged by meter readings, tank gage glass level, and line and component holdup volumes established previously. All subsequent operations are performed using this one tank with recirculating fuel.

Circulate at 40 gpm through the cleanup filter-separator (bypassing the test housing) until the fuel is clean and dry as determined by Totamitor readings and sample analyses as required. The fuel temperature should be adjusted to approximately 80°F during this time.

Circulate at 40 gpm through the main fuel bypass (bypassing both the test housing and the cleanup filter-separator). Inject the required amount of corrosion inhibitor over a 15-min period, then inject the required amount of fuel system icing inhibitor over a 15-min period and flush the injection system and lines with test fuel. Direct the main fuel flow through the cleanup filter-separator (but bypass the test housing), and continue to recirculate for a minimum of 15 min at 40 gpm. Recheck the cleanliness of the fuel.

Note: The preceding step is omitted when additive-free fuel is being tested.

Inspect and clean the mixing screen, or install the screen if it has been omitted from the screen housing during the preceding operations.

Set the fuel flow rate at 20 gpm, set totalizing flowmeter reading at zero, and direct the fuel flow through the test housing and cleanup filter-separator. Recirculate for 15 min. During this "pre-test" period, adjust flow rates and temperatures, check operation of all instruments, take samples as required, and have the water injection system running and ready to direct the flow into the fuel line.

*Filtered tap water was used in some of the later tests in the program.

At the end of the 15-min pre-test period, start timing the run and direct the water flow into the fuel line. Take readings and draw samples as indicated in subsequent paragraphs. When the water level in the test housing covers the openings in the canister base, drain water at a rate that will maintain a stable level in the housing.

During the 60-min test period with water injection, prepare the solids injection system for operation and calibrate the dirt feeder, if this has not been done previously. Five min before the end of this 60-min period, direct fuel flow at 3 gpm into the swirl hopper, and turn on the solids injection pump; regulate the pump speed to maintain a stable fuel level in the swirl hopper.

After 60 min of test time, start the dirt feeder. Continue to inject both solids and water until the pressure drop across the test housing reaches 40 psi. At that time, cut off the dry-dirt feed, take final samples, and shut down the fuel flow.

Record test housing pressure drop and Totamitor readings every 10 min throughout the run, and also (1) 35 min after the start of solids injection, i.e., after 95 min of test time, (2) when the pressure drop reaches 20 psi, and (3) when the pressure drop reaches 40 psi. Totamitor readings are taken from the recorder charts after the run, and any peaks occurring between the regular readings should be noted. Record screen pressure drops, cleanup filter-separator pressure drops, and totalizing flowmeter readings approximately every 30 min of test.

Draw samples for analysis as follows:

Clean influent fuel – solids	Pre-test, 30, and 95 min
Same – WSIM, IFT, and FSII content	Pre-test and 95 min
Effuent fuel – solids and free water	30, 95, and 130 min, and 20 and 40 psi
Injection water – solids	30 min
Same – pH and surface tension	30 and 95 min
Coalesced water – pH, surface tension, and FSII content	30 and 95 min

Remove the coalescer element from the housing without losing any test dust, rinse in isopropanol and then petroleum ether, dry to constant weight, and record the weight to the nearest gram.

If the same fuel is to be reused in the subsequent test, analyze for FSII and reblend to the required level, then continue with the next test.

If the next test requires fresh fuel, pump the used fuel to scrap storage and drain the loop system thoroughly.

Bring in base fuel (same as used for the next test) and circulate through the cleanup filter-separator at 40 gpm for 30 min, then, discard this fuel and drain the loop thoroughly. Repeat with a fresh batch of uninhibited fuel, but this time bypassing the cleanup filter-separator. During this time, replace the cleanup filter-separator elements with fresh elements. Discard and drain the second flush. Then, bring in fresh uninhibited fuel and start the new test sequence as described previously.*

c Procedure 11

This is essentially the MIL-F-8901A inhibited-fuel test procedure as adapted for the AF/SS loop. The test fuel is JP-5 containing 16 lb/Mbbl of Santolene C but no FSII, freshly blended fuel is prepared for each test. Solid

*Cleanup filter separator elements need not be replaced if the next run is to be made on a new fuel blend of the same composition.

contaminant is coarse AC dust injected at a rate of 5.72 g/min, thus loading the element to rated capacity in 35 min of solids injection or 95 min of testing. Except for the drawing of samples for AEL determination of free-water content and certain special samples for modified Karl Fischer determinations of total water content, the sampling schedule follows that of 8901A. Below is the sample schedule that is used:

Effluent-fuel – solids	65, 70, 80, 95, 110, 120, 130 min; 20, 30, 40 psi
Effluent-fuel – K-F	5, 10, 20, 30, 40, 50, 60, 70, 80, 95, 110, 120, 130 min; 20, 30, 40 psi
Clean-fuel – K-F	30, 60, 95, 130 min; 20, 30, 40 psi
Clean-fuel – saturation	Pre-test
Effluent-fuel – AEL, line (2) and bottled (2)	95 min 20, 30, 40 psi
Clean-fuel – WSIM	Pre-test
Clean-fuel – IFT	Pre-test; 40 psi
Injection water – solids, pH, surface tension	50 min

In actual operation, it was found that the 20-, 30-, and 40-psi samples along with the 80- and 95-min samples came so close together that it was impossible to get them all. Also, it was found that in all tests, the pressure drop reached 40 psi in 95 min or less, so that there were no subsequent samples.

d. Procedure 12

This is essentially the MIL-F-8901A red iron oxide emulsion test, commonly termed the "slurry test." Briefly, the test procedure consists of injecting 3% water and 0.0035 lb of slurry per gallon of fuel until the pressure drop reaches 40 psi. The slurry consists of 0.1 lb of I-116 red iron oxide per pound of 50-50 water-fuel mixture, thus containing 9.09% of oxide by weight. The solids injection rate is 0.145 g per gallon of fuel, or 2.89 g/min in a 20-gpm test. At this rate, the nominal dirt-holding capacity of 200 g is reached in approximately 70 min of injection.

In the tests reported here, the test fuel was uninhibited JP-5, instead of the VV-K-220 kerosene specified in MIL-F-8901A. As in Procedure 11, certain additions were made to the sampling schedule, resulting in the following:

Effluent-fuel solids	5, 10, 20, 30, 40, 50, 60, 70 min; 10, 20, 30 40 psi
Effluent-fuel K-F	Same as above
Clean-fuel K-F	10, 20, 30, 40 psi
Clean-fuel saturation	Pre-test
Effluent-fuel AEL, line (2) and bottled (2)	10, 20, 30, 40 psi
Injection-water solids, pH, surface tension	50 min

It was found that there was some "pile-up" in sample scheduling and slight modifications had to be made to fit the behavior of the individual tests.

The method of preparing and injecting the slurry is somewhat different than that described in MIL-F-8901A. Slurry of standard composition is prepared prior to test in a slurry mixing tank with recirculating pump (see Figure 2). This system had been designed to handle thin slurries, and the pump capacity and line sizes are inadequate to do a thorough mixing job on thick slurry. Therefore, the pump is used only to keep the bottom of the mixing tank clear by recirculating, with no back pressure other than pressure drop in the lines. The actual mixing of the slurry is performed with a mechanical stirrer (propeller type), which is run continuously while preparing and injecting the slurry.

Slurry from the recirculating line is picked up by means of a peristaltic pump and metered into the injection hopper, where it is picked up by the fuel stream and solids injection pump, i.e., handled just as if it had been dry dirt. Metering of the slurry is reasonably accurate, but there are problems with deposition of red iron oxide in the slurry mixing tank and deposition of slurry in the injection hopper. When slurry is metered into the swirling fuel stream in the hopper, it becomes very evident that the feed rate into the main fuel line is erratic because of temporary hang-up of slurry globules, and also that the slurry is very resistant to dispersal in fuel. In order to avoid the temporary and sometimes permanent hang-up of slurry globules in the injection hopper, the slurry feed line is direct to the center of the hopper, i.e., where the slurry will drop directly into the inlet of the Moyno injection pump.

e. Procedure 13-A

This procedure is similar to Procedure 10 except for major changes in the schedule of water and solids injection, which in turn affect the sampling schedule. The only other significant change (in comparison with Procedure 10) is the use of filtered tap water rather than synthetic water. The solid contaminant is coarse AC dust (same as Procedure 10). The fuel flow rate is 20 gpm, the fuel supply pressure is 70 psi, and the fuel temperature entering the test section is 80°F. The following test schedule is used:

0 min to 20 psi	Water 0.002 gpm, solids 5.72 g/min
Next 15 min:	Water 0.2 gpm, no solids
Remainder (to 40 psi):	Water 0.2 gpm, solids 5.72 g/min

The corresponding ratios of contaminants to fuel are: water 0.01 and 1% of fuel flow, and solids 0.286 g/gal. At this solids injection rate, the element reaches nominal dirt-holding capacity of 200 g in 35 min of dirt injection.

Totamitor readings and test-section pressure drop are recorded every 5 min and at 20 and 40 psi, test-section inlet temperature every 15 min, and totalizing flowmeter readings, screen pressure drop, and cleanup filter-separator pressure drop at the start and end of the test. The following sampling schedule is used:

Effluent-fuel AEL	5 min; 20 psi, 5, 10, and 15 min after 20 psi; 40 psi
Effluent-fuel solids	5 min; 20 psi, 5 min after 20 psi; 40 psi
Influent-fuel WSIM and IFT	Pre-test
Influent-fuel FSII	Pre-test, post-test
Injection-water solids, pH, and surface tension	Post-test
Coalesced water	Periodic visual examination

f. Procedure 13-B

Same as 13-A, except no water is injected during the initial solids injection period (0 min to 20 psi).

g. Procedure 13-C

Same as 13-A, except water injection rate is increased to 0.6 gpm (3%) starting at 20 psi and continuing to end of test.

h. Procedure 13-D

Same as 13-A up to the 20-psi point; then water and solids injections are shut off, and fuel flow is continued for 8 hr additional. After an 8-hr shutdown, fuel flow is restarted, and the regular schedule of Procedure 13-A is resumed as if starting from the regular 20-psi point (15 min of 0.2 gpm water, then water plus solids to 40 psi).

i. Procedure 13-E

Same as 13-A, except solid contaminant is I-116 red iron oxide.

j. Procedure 13-F

Same as 13-A, except solids (coarse AC dust) injection rate is 25% of normal, i.e., 1.43 g/min.

k. Procedure 13-G

Same as 13-A, except the following schedule is used:

0 min to 10 psi	Water 0.002 gpm, solids 5.72 g/min
Next 15 min	Water 0.2 gpm (no solids)
Subsequently	Fuel flow rate increased every 15 min in 2-gpm increments to a maximum of 32 gpm, keeping water injection rate at 1% of fuel flow rate. Water rate then increased stepwise to 1.2 gpm and later decreased to 0.032 and 0.0032 gpm.

l. Procedure 13-H

Same as 13-A, except water is injected into fuel pump suction. Also, after regular schedule is completed, solids injection is discontinued and water injection is continued at 0.2 gpm, while reducing fuel flow rate every 15 min in 2-gpm increments down to 10 gpm.

m. Procedure 13-I

Same as 13-A, except fuel flow rate is 16 gpm and water is injected into fuel pump suction.

n. Procedure 13-J

Same as 13-A, except solid contaminant is fine AC dust.

o Procedure 13-K

Same as 13-A, except solid contaminant is fine AC dust, and water injection rate is 0.2 gpm throughout test.

p. Procedure 13-L

Same as 13-A, except solid contaminant is fine AC dust, water injection rate is 0.2 gpm throughout test, and dirt injection is scheduled as follows: First injection terminated at 10 psi, then 120 min without dirt injection, then dirt injection restarted and continued to 40 psi.

q. Procedure 13-M

Same as 13-A, except solid contaminant is Pfizer R-9998 red iron oxide

r. Procedure 13-N

Same as 13-A, except solid contaminant is fine AC dust, and solids injection rate is 50% normal (2.86 g/min).

s. Procedure 13-O

Same as 13-A, except solid contaminant is 50% fine AC dust and 50% coarse AC dust (by weight).

t. Procedure 13-P

Same as 13-A, except solid contaminant is Pfizer B00985 ground iron ore.

u. Procedure 13-Q

Same as 13-A, except solid contaminant is Chemical Commerce Co. "N" black magnetic iron oxide.

v. Procedure 14

Same as 13-A, except test consists of five 4-hr cycles and a final cycle, with at least 10-min shutdown between cycles:

Each 4-hr cycle:	Water 0.002 gpm throughout, solids 5.72 g/min until pressure drop reaches 20 psi.
Final cycle:	Water 0.2 gpm, solids 5.72 g/min; test terminated when pressure drop reaches 40 psi.

w. Procedure 14-A

Same as Procedure 14, except solid contaminant is fine AC dust, and final cycle is omitted if pressure drop has reached 40 psi in a previous cycle. If a final cycle is necessary, it is run at the end of the fourth cycle without intermediate shutdown.

x. Procedure 14-B

Same as Procedure 14, except solid contaminant is fine AC dust, and solids injection cutoff point is 10 psi instead of 20 psi. Cycle schedule is the same as in 14-A

y. 8901B Procedures

(1) Inhibited Fuel Test

Although this procedure is quite similar to Procedure 11, there are a few important differences between the two. The fuel used is JP-5 with 16 lb/Mbbl of Santolene C and 0.15% FSII. As in Procedure 11, the

solid contaminant is coarse AC dust but it is injected at a rate of 2.86 g/min instead of 5.72 g/min, thus loading the element to rated capacity in 70 min. Two of these tests were run, one at 40 gpm and one at 30 gpm. No samples for Karl Fischer determinations of free water are drawn at any time during the test. The following is the sample schedule that is used; this differs slightly from 8901B.

Influent-fuel WSIM, IFT, FSII	Pre-test and post-test
Effluent-fuel solids and AEL	5, 10, 20, 30, 40, 50, 60 70, 80, 90, 100, 110, 120, 130 min; 40 psi
Injection-water solids, pH, and surface tension	Post-test

(2) Media Migration Test

Briefly, this test consists of subjecting an element to fuel at six different flow rates ranging from 6 to 34.5 gpm for 10-min periods, and sampling the effluent fuel for solids content determination. No solid contaminant or water is injected at any time during the test. The following sample schedule is used:

Influent-fuel WSIM, IFT	Pre-test
Effluent-fuel solids	5, 10, 20, 30, 40, 50, 60 min

(3) Dry Red Iron Oxide Test

In this test, red iron oxide (Fisher I-116) is injected into a fuel flow of 30 gpm* at a rate of 2.86 g/min; no water is injected at any time during the test. At this rate, the element is loaded to its specified solids capacity of 10 grams per gpm of rated flow in 70 min. The test is continued until structural failure of the element becomes apparent or, if no failure occurs, until a differential pressure of 75 psi is reached. The sample schedule is as follows:

Influent-fuel WSIM, IFT, FSII	Pre-test, post-test
Effluent-fuel solids	0, 5, 10, and each 10 min until 40 psi is reached; 40 psi and at each additional 5-psi difference thereafter

(4) Water Removal Test

As adapted to the Al/SS loop, this test consists of subjecting an element to a 34.5-gpm fuel flow for the first hour, and a 32.8-gpm fuel flow for the second hour of the test. No solid contaminant is injected at any time during the test. Water is injected at a rate of 0.17 gpm during the first hour, and 1.32 gpm during the second hour of the test. The following is the sample schedule used:

Influent fuel WSIM, IFT, FSII	Pre-test, post-test
Effluent-fuel AEL	Every 10 min during first hour; every 5 min during second hour.
Injection-water solids, pH, surface tension	Post-test

*MIL-F-8901B calls for flow rate to be that for which the elements are rated; in the tests reported herein, elements rated at 20 gpm were tested at a flow rate of 30 gpm.

(5) Red Iron Oxide and Water Test

Conditions for this test are a fuel flow of 30 gpm*, a water injection rate of 0.9 (3.0% of fuel flow) and a solids injection rate of 2.86 g/min of red iron oxide (Fisher I-116). These conditions are maintained from 0 min of testing until a 40-psi differential pressure is reached across the element. Below is the sample schedule that is used:

Influent-fuel WSIM, IFT, FSII	Pre-test, post-test
Effluent-fuel, solids, AEL	5 min and every 5 min thereafter; 40 psi
Injection-water solids, surface tension, pH	Post-test

(6) Modified Inhibited Fuel Test

This test is identical to the inhibited-fuel test except that red iron oxide (Pfizer B9998) is used in place of coarse AC dust, and corrosion inhibitors other than Santolene C, in differing concentrations, may be used. Test using this procedure may also be run on fuel containing no inhibitors. The sample schedule is the same as for the inhibited-fuel test. Fuel flow rate is 20 gpm.

2. Clay Treating Procedure

a. General

The procedure listed here is used to clay treat a batch of fuel in preparation for a subsequent single-element loop test. The procedure is written primarily for fuels containing FSII and corrosion inhibitors, but can be used with minor modifications for other fuels. Fuel is treated by pumping from one of the loop tanks through the clay filter, and into the other tank. This is repeated for two or more passes through the clay filter. The fuel volume treated is normally 600 gal; it may be fresh, additive-free fuel, or it may be additive-containing fuel remaining after a single-element loop test.

Fuel is not normally discarded between runs; i.e., the same fuel, plus makeup, is used from test to test. Ordinarily, the loop is not flushed between runs, and cleanup filter-separator elements remain unchanged from run to run, even when changing from one inhibitor to another. During a loop test on a filter-separator element, the clay filter is bypassed; it is used only for clay treating between runs.

b. Nomenclature

The following nomenclature has been adopted for reporting clay-filter operations:

Influent sample	Fuel drawn from line entering filter-separator test section in Al/SS loop
Clay-treated fuel	Test section influent after clay treatment, without the addition of any inhibitor
Pre-test sample	Test section influent during regular pre-test period; contains inhibitors if same were added for test

*MIL-F-8901B calls for flow rate to be that for which the elements are rated; in the tests reported herein, elements rated at 20 gpm were tested at a flow rate of 30 gpm.

Post-test sample	Test section influent after completion of a single-element test
Fuel volume treated	Amount of fuel in system subjected to clay treatment (excluding residual fuel in clay-filter housing from previous run, which has been treated previously)

c. **Outline of Procedure**

With the correct volume of fuel in one tank, it is pumped at 40 gpm through the cleanup filter-separator and clay filter to the other tank, then back to the first tank; the direction of flow through the cleanup filter-separator and clay filter is the same in both of the two passes. This back-and-forth pumping is repeated for a total of two or more passes. The fuel, in the original tank, is then recirculated for 5 min at 40 gpm through the cleanup filter-separator and clay filter, and the "clay treated fuel" is sampled and analyzed for WSIM, IFT, and FSII content. The clay-treated fuel may be held for a maximum of 72 hr before use in a loop test; if held longer, it must be re-treated.

The clay-treated fuel is then blended with inhibitors as required for the subsequent test. It is assumed that the clay-treated fuel contains absolutely no corrosion inhibitor, i.e., that such materials have been removed 100% by the clay treatment. The actual FSII content of the clay-treated fuel, as determined by analysis, is used to calculate the FSII makeup requirement.

The treated fuel is then used to run a single-element loop test. Pre-test and post-test fuel samples are analyzed for IFT, WSIM, and FSII content in addition to any other analyses specified in the single-element loop test procedure.

d. Specific Test Sequences

When fresh fuel is to be charged to the loop, the system is first drained thoroughly, including the cleanup filter-separator and clay-filter housings. The loop is not ordinarily flushed, nor are the cleanup filter-separator elements changed. One of the tanks is loaded with outside fuel (normally uninhibited fuel) in amount of 600 gal plus allowance for clay-filter holdup, line holdup, and losses. This fuel is recirculated for 5 min at 40 gpm through the cleanup filter-separator only, and sampled for IFT and WSIM. It is then clay-treated with four passes, after which it is used in a subsequent single-element test.

For a repeat test on the same inhibitors, no draining, flushing, or element change is required. Fuel losses in the previous test are made up with outside fuel; the fuel is clay-treated with two or more passes and then used in a single-element test.

When changing corrosion inhibitor (assuming that all tests are run with FSII present in the fuel), the sequence is identical to that used for repeat tests on the same inhibitor, except that four passes are used in the clay treating.

Fuel may be reused, and the same set of clay-canister elements may be continued in service, so long as the treating continues to restore the fuel to "uninhibited-fuel quality," as evidenced by high values for WSIM and IFT

Records on cumulative fuel volumes treated and clay-filter throughput are kept for each set of clay-canister elements, the volumes being broken down into uninhibited and inhibited fuel.

3. **Analytical Techniques**

a General

Six types of analytical tests were made in conjunction with most of the loop tests described in this report. Using techniques described in this section, analyses were made on influent fuel, effluent fuel, and injection water

b. Influent Fuel

(1) Water Separation Index Modified (WSIM) Determination

The method used followed ASTM D 2550-66T except for deviations in the test fuel flush (amount and scheduling), in the scheduling of coalescer cell installation, and in the use of both hot and cold water (65 to 90°F) for temperature control instead of the use of only cold water as prescribed in ASTM D 2550-66T.

Two test fuel flushes of 180 to 220 ml rather than 200 to 250 ml were used prior to calibration of the output meter. Immediately after the second test fuel flush, the coalescer cell assembly was installed and the calibration of the output meter was then effected using 400 to 600 ml of test fuel.

(2) Interfacial Tension (IFT) Determination

In this determination, a platinum ring was pulled upward through a water-fuel interface and the required force was measured. All determinations of this type were made using a Fisher Tensiomat Model 21 according to instructions supplied by the manufacturer and in general accordance with ASTM D 971-50. A few important deviations from this method, however, were made. Instead of rinsing in petroleum naphtha or benzene followed by rinsing in mehtyl ethyl ketone, the ring was cleaned by rinsing in benzene or toluene followed by rinsing in acetone. Also, the interface aging time was always 45 to 75 sec. Lastly, samples for analysis were never filtered prior to this determination.

*(3) Fuel System Icing Inhibitor (FSII) Determination**

In this test, FSII was removed from a sample of fuel by extraction with water. The amount of icing inhibitor in the extract was then determined by measuring the difference between its refractive index and that of the water used in making the extraction. The test method is described in FTMS-791a Method 5340.

A Seiscor Model AC-500 differential refractometer was used. However, the procedure deviated from the manufacturer's directions and from the FTMS-791a method. A major deviation was the use of fuel-FSII blends rather than water-FSII blends in preparing the cell calibration curve. Other deviations used in an effort to refine the method and make the determination more accurate and reproducible were the use of a second separatory funnel in which the FSII-extract solution could separate further from remaining traces of fuel and the use of a polypropylene needle on the second separatory funnel to facilitate filling of the cell.

c. Effluent Fuel

(1) Solids Content Determination

The method used followed the laboratory filtration method described in ASTM method D 2276-67T. A known volume of fuel was filtered through a preweighed test membrane filter and the increase in membrane filter weight was determined after washing and drying. The change in weight of a control membrane filter located immediately below the test membrane filter was also determined. The total contamination was then determined from the increase in weight of the test membrane filter relative to the control membrane filter.

The only major deviation from the ASTM method named was the addition of a color rating of the test membrane filter after the filtration, drying, and weighing.

(2) AEL Free Water Determination†

With the AEL method, effluent fuel water content was measured using a porous pad which was coated with a water-sensitive uranine dye. When fuel containing free water was passed through the water-detector pad, a change occurred in the dye at the point of contact of each water droplet. This change caused the dye to

*This determination is described in detail in Section VIII-5 of this report.
†Evaluations of the AEL method of free water determination are described in earlier reports.[1,6]

fluoresce brightly when the pad was exposed to ultraviolet light. By using a measured sample volume, and comparing the pad with known standards, it was possible to obtain a relative rating of free water content.

AEL free water analysis was performed on line samples at the sampling port using water-detector pads conforming to MIL-D-81248 (WP) and the following sampler components available from Millipore Filter Corporation:

No. XX64 037 03	Quick-release valve
No. XX64 037 08	Sampler with inlet hose and valve assembly and 1000-ml polyethylene bottle
No. XX64 037 75	Stainless steel monitor case

The ultraviolet light pad-viewer and set of AEL standards conformed to MIL-V-81227 (WP) and MIL-S-81282 (WP), respectively.

In an earlier report[(6)], the AEL free water detector was evaluated for accuracy of ratings. Results of that evaluation indicated that for direct line samples from the Al/SS loop, there was a clear relation between sample size and AEL rating. The optimum sample was indicated to be slightly less than 300 ml for best agreement of AEL rating with free water content of the fuel. Other measurements, made in a batch-blending system which was sealed to prevent water exchange between the fuel and the atmosphere, indicated that the optimum sample size was 275 ml. These results suggest very strongly that the "as-read" AEL ratings for 500-ml direct line samples reported herein are higher than the actual free water content. The AEL ratings obtained in loop tests and reported here* are direct, "as-read" values. The sample-size correction was omitted for two reasons: (1) it is not certain that a correction factor based on results[(6)] obtained with uninhibited JP-5 fuel can be universally used, and (2) as far as comparison and statistical analyses are concerned, the conclusions that are drawn will be the same whether the AEL ratings are multiplied by a factor or not.

d. Injection Water

(1) Determination of pH

A Leeds and Northrup pH indicator (Model 7401) was used according to the manufacturer's instructions.

(2) Solid Content Determination

As in the case of the effluent fuel solids determination, this method followed closely ASTM method D 2276-68T of laboratory filtration, but was modified for use with water samples. Instead of the commonly used 0.8-μ Millipore membrane filters, metallic 0.8-μ filters (Flotronics Inc. Cat. No. FM 47-80) were used. Filtered distilled water had to be used, rather than petroleum ether, to rinse out the sample bottles. As in the determination of effluent fuel solids, a known volume of water was filtered through a pre-weighed filter and the total contaminant was determined from the increase in weight of the filter after washing and drying. However, in analyzing water samples, no control filters were used, since the silver membranes are insensitive to variations in washing and procedures or to changes in ambient humidity.

(3) Surface Tension (ST) Determination

The technique used was essentially the method described in ASTM D 971-50. After having obtained satisfactory values (71 to 72 dynes/cm) for the surface tension of distilled water, a sample of injection water was tested in the same way. This sample was drawn downstream of the water injection system filter and was not refiltered prior to the determination. A Fisher Tensiomat Model 21 was used. One notable deviation from the ASTM method was that the platinum ring was cleaned by immersing first in benzene or toluene and then acetone rather than in petroleum naphtha or benzene and then methyl ethyl ketone.

*In the small-scale coalescence results reported in Section VII, AEL rating corrections were made.

SECTION V

LOOP TEST RESULTS AND DISCUSSION

1. General

The loop test results used in the analyses which follow can be divided into four groups. One group designated as "fuel quality parameters" includes WSIM and IFT measurements taken at three different times: post-clay treatment, pre-test, and post-test. The second group designated as "injection water quality parameters" includes injection water surface tension, pH, and solids content measurements. The third group of results, designated as "element physical parameters," includes element weight, element differential pressure measured in the pressure-check trough, and differential pressure measured in the AJ/SS loop at zero-minutes test time. The fourth group of results, designated as "element performance parameters," includes element weight gain, percent dirt load at 20 psi and at 40 psi, average and maximum AEL free water rating of effluent, average and maximum solids content of effluent, and average and maximum Totamitor readings on effluent fuel.

Statistical, graphical, and other analyses of the aforementioned parameters were performed as deemed necessary in order to study various aspects of single-element filter-separator testing as follows:

- Level and variation in fuel quality parameters during tests and the extent of correlation between these parameters and the element performance parameters
- Effects of clay treatment of fuel on fuel quality and element performance parameters
- Effect of variations in injection water quality on element performance parameters
- Variations in element physical parameters and the effect of these variations on element performance parameters
- Effects of additives on fuel quality and element performance parameters
- Relationships between element performance parameters

In addition, the last subdivision of this section deals with special tests and tests not sufficiently replicated to be amenable to statistical analysis.

2. Test Groupings

In order to make it easier to use information from the test data presented in the Appendix of this report and the Appendix of an earlier report[5], several tables are presented which list tests carried out under certain conditions.

In Table 9, tests conducted on JP-4 fuel are identified as to procedure and fuel condition, fresh or reused. Similar information for tests conducted on JP-5 fuel is given in Table 10.

Tables 11 and 12 identify tests run on JP-4 and JP-5, respectively, grouped according to additives but without regard to FSII content. Table 13 identifies tests run at three different levels of FSII content for both JP-4 and JP-5.

TABLE 9 TESTS INVOLVING JP-4 FUEL

Procedure	Fuel condition	
	Fresh	Reused
19	48,49,56-60,61A	50-55,61B,62
13-A	212-219	...

Table 14 identifies tests as to both type of injection water and type of solids contaminant. Tests on both JP-4 and JP-5 are included.

TABLE 10. TESTS INVOLVING JP-5 FUEL

Procedure	Fuel condition			
	Fresh	Reused	Fresh clay-treated	Reused clay-treated
10	63,64,66, 69-83,91-100, 110,134,138,142, 143,148	65,67,68	---	---
11	84,85,86	---	---	---
12	88,90	89		
13-A	101,109,125,132, 133,136,137,140, 141,144,146,147, 184-211,243-246	---	220,247,248, 261,289,304	221-242,249-255, 262-288,290-298, 305-313
13-B	102	---	---	---
13-C	103	---	---	---
13-D	104	---	---	---
13-E	105	---	---	---
13-F	106	---	---	---
13-G	111	---	---	---
13-H	112	---	---	---
13-I	114	---	---	---
13-J	115,126-131,135, 139,145,149-151, 154,155,157,159, 161,162,170,172,176- 179,225-229	---	---	---
13-K	116	---	---	---
13-L	117	---	---	---
13-M	124	---	---	---
13-N	152,153,156,158, 160,163-165,171, 173	---	---	---
13-O	166-169,174,175, 130-183	---	---	---
13-P	---	---	---	315-322
13-Q	---	---	---	323,324
14	108	---	---	---
14-A	118,119,121-123	---	---	---
14-B	120	---	---	---
MIL-F-8901B inhibited fuel test at 40 gpm	---	---	256	---
Media migration	258A	---	259A	---
Dry RIO test	258B	---	259B	---
Water removal	---	---	---	260A
RIO and water	---	---	---	260B
Modified inhibited fuel test	---	---	314,328	325-327, 329
		---	---	
Inhibited fuel test at 30 gpm	---	---	257	---

TABLE 11. TESTS INVOLVING JP-4 PLUS ADDITIVES WITHOUT REGARD TO FSII CONTENT

Additives	Test numbers
None	48-51,60
4 lb/Mbbl Snt	52,53,62
16 lb/Mbbl Snt	54,55
4 lb/Mbbl AFA	56,212,213
4 lb/Mbbl AFA + 1 mg/ℓ ASA	214-216
1 mg/ℓ ASA	217-219
5.5 lb/Mbbl Tol	57,58
5 lb/Mbbl Lubr	59

TABLE 12. TESTS INVOLVING JP-5 PLUS ADDITIVES WITHOUT REGARD TO FSII CONTENT

Corrosion inhibitor	Other additive	Test numbers
None	None	63,80,81,87-90,129-131,258A-260B, 299-303B
None	0.60,0.80 mg/ℓ ASA	61A,61B
None	1.00 mg/ℓ ASA	217-219
None	0.02 mg/ℓ PtL	186
None	0.05 mg/ℓ PtL	187,188
None	0.20 mg/ℓ PtL	185
None	1.00 mg/ℓ PtL	184
None	0.02 mg/ℓ PtCR	189
None	0.05 mg/ℓ PtCR	190
None	0.10 mg/ℓ PtCR	191
None	0.20 mg/ℓ PtCR	192
None	0.25 mg/ℓ PtCR	193,195
None	0.50 mg/ℓ PtCR	196
None	1.00 mg/ℓ PtCR	194
None	1.00 mg/ℓ NC-2	197
None	10.00 mg/ℓ NC-2	198
None	50.00 mg/ℓ NC-2	199
None	0.50 mg/ℓ NA-1	203
None	1.00 mg/ℓ NA-1	201
None	5.00 mg/ℓ NA-1	200
None	10.00 mg/ℓ NA-1	200
4 lb/Mbbl Snt	None	52,53,62,69,159,160,165
16 lb/Mbbl Snt	None	54-68,70-79,83-86,91-99, 125-128,161-164,166-168,204,220-229, 256,257,261-272,317,318,320,323, 324
4 lb/Mbbl AFA	None	56,157,158,205-213
10 lb/Mbbl AFA	None	314,325,327,329
16 lb/Mbbl AFA	None	100-108,121-124,150-156,174, 175,230-234,273-298,315,316
5.5 lb/Mbbl Tol	None	57,58,140,144
20 lb/Mbbl Tol	None	141-143,145,248,249
5 lb/Mbbl Lubr	None	59,146
20 lb/Mbbl Lubr	None	147-149,250-252,289-298,304-313, 321,322
7 lb/Mbbl RP	None	172,173
20 lb/Mbbl RP	None	109-120,169-171,235-247
14.5 lb/Mbbl EDS	None	132,135
9 lb/Mbbl Uni	None	136,176,177,180,181
20 lb/Mbbl Uni	None	137-139,178,179,182,183,253-255

TABLE 13. TESTS INVOLVING JP-4 OR JP-5 AT DIFFERENT FSII CONCENTRATIONS

FSII concentration, vol %	Test numbers	
	JP-4	JP-5
0	48,49	63,73,84-90,184-203,258A, 258B,259A,259B,328
0.10	---	207-219
0.15	50-60,61A, 61B,62	64-72,74-83,91-183, 205,206,220-257, 261-298,304-327,329

TABLE 14. TEST GROUPING BY INJECTION WATER TYPE AND SOLID CONTAMINANT

Contaminants	Test numbers
No water, no solids	258A,259A
No water, red iron oxide (I-116)	258B,259B
Filtered tap water, coarse AC dust	48,96,99,101,102-104,106,108,109, 111-114,125,132,133,136,137,140-144, 146-148,184-203,205-224,230,257, 261-298,304-313
Filtered tap water, fine AC dust	115-123,126-131,135,139,145,149-165, 170-173,176-179,225-229
Filtered tap water, red iron oxide (I-116)	105
Filtered tap water, red iron oxide (R9998)	124,314,325-329
Filtered tap water, ground iron ore	315-322
Filtered tap water, magnetic black iron oxide	323,324
Filtered tap water, 50% coarse + 50% fine AC dust	166-169,174,175,180-183
Type B synthetic water, coarse AC dust	49-56,58-60,61A,61B,62-73,77,80, 84-86,91,100,110,134,138
Type B synthetic water, red iron oxide (I-116)	88-90
pH 5 (distilled water + NaCl + NaOH), coarse AC dust	74
ph 7 (distilled water + NaCl + NaOH), coarse AC dust	75
pH 10 (distilled water + NaCl + NaOH), coarse AC dust	76
65% type B+ 35% FSII, coarse AC dust	78,79,81
Distilled, coarse AC dust	95
pH 9.5 (type B+ NaOH), coarse AC dust	92
Type B+ NaCl, coarse AC dust	82,83
Contaminated distilled water, from previous test, coarse AC dust	93,94
pH 9.5 (distilled + $NaHCO_3$ + NaOH), coarse AC dust	97

Table 15 groups tests according to filter-separator element identification.

TABLE 15. TESTS INVOLVING DIFFERENT FILTER-SEPARATOR ELEMENTS

Element identification	Test numbers
Filters Inc, lot 286	48-60,61A,61B,62 3
Filters Inc, lot 428	84-90
Filters Inc, lot 440	91-150
Filters Inc, lot 440A	151-199
Filters Inc, lot 465	200-257,258A,258B, 276,278,282,287,290,296, 304,308
Filters Inc, lot 516	259A,259B,260A,260B,315-324
Filters Inc, Govt. Std.	310-313
Fram, lot 14 CC-S11B	261,264,265,268,273,280,281, 288,289,295,298,307
Bendix, part no. 04580004	262,266,267,269,274,279,284, 285,292,294,297,306
Bendix, part no. 04580004 ID 69 M2814 (special RIO)	314,325,326
Bowser, part no. A1389B	263,270-272,275,277,283,286,291, 293,305,309
Bowser, part no. A1389B (special RIO	327-329

3. Data Used

The data used fall into five classifications: test condition, fuel quality parameter, water quality parameter, element physical parameter, and element performance parameter. The 53 data items used in the computer analysis are listed and described in Table 16. These data were extracted from the Test Data Summary Sheets given in the Appendix of this report and in the Appendix of Reference (5), as well as from the data sheets of the various analytical tests performed on sample fuel.

Most of these data items are fully defined by the descriptions given in the table. Some additional remarks are needed to clarify the meaning and method of determination of certain parameters related to the elements.

The two values for "element ΔP" are determined at the start of a given loop test. The value determined in the open trough represents the resistance of the element itself to flow of uninhibited JP-5 fuel at 20 gpm. The value determined at "0 min" represents the resistance of the entire test unit including housing, element, and canister, measured under actual test conditions. Strictly speaking, this latter value (0 min) is not the element differential pressure although the element surely contributes most of the resistance. As discussed in Section VIII-3 of this report, the actual contribution of the element cannot be determined from measurements on the housing. Thus, the two values obtained (in the trough and in the loop) must be regarded as two separate measures of element flow resistance.

TABLE 16. LISTING OF TEST DATA USED IN COMPUTER ANALYSES

Datum	Description
Test conditions	
Test no.	
Fuel	JP-4: fresh or reused JP-5: fresh, reused, fresh clay-treated, or reused clay-treated.
Fuel batch no.	Batches 14-25
Procedure	Thirty procedures as described in Section IV
Corrosion inhibitor	Seven inhibitors plus uninhibited
Corrosion inhibitor concentration	Concentration in lb/Mbbl
Other additive	Includes anti-static additive and surfactants
Other additive concentration	Concentration in mg/ℓ
Blended FSII concentration	0,0.1, or 0.15 vol %
Element manufacturer	Filters Inc, Fram, Bendix, or Bowser
Element lot or identification	Identification of 13 different lots
Type of injection water	Identification of 13 different waters
Type of solids	Identification of 7 different solids
Gallons of water injected	A measure of fuel washing based on the water injection rate in gpm X the time during which water was injected.
Fuel quality parameters	
Post-clay WSIM	Measurement taken on sample fuel drawn immediately after clay treatment.
Pre-test WSIM	Measurement taken on sample fuel drawn immediately before test.
Post-test WSIM	Measurement taken on sample fuel drawn immediately after test.
Post-clay IFT	Measurement taken on sample fuel drawn immediately after clay treatment.
Pre-test IFT	Measurement taken on sample fuel drawn immediately before test.
Post-test IFT	Measurement taken on sample fuel drawn immediately after test.
Post-clay FSII	Measurement taken on sample fuel drawn immediately after clay treatment.
Pre-test FSII	Measurement taken on sample fuel drawn immediately before test.
Post-test FSII	Measurement taken on sample fuel drawn immediately after test
Post-clay WSIM disk stain color	Color of stain on fine media disk rated as none, light, medium or dark.
Pre-test WSIM disk stain color	Color of stain on fine media disk rated as none, light, medium or dark.
Post-test WSIM disk stain color	Color of stain on fine media disk rated as none, light, medium or dark.

TABLE 16. LISTING OF TEST DATA USED IN COMPUTER ANALYSES (Cont'd)

Datum	Description
Post-clay WSIM disk stain size	Diameter of stain on fine media disk, 16th in.
Pre-test WSIM disk stain size	Diameter of stain on fine media disk, 16th in.
Post-test WSIM disk stain size	Diameter of stain on fine media disk, 16th in.
Water quality parameters	
pH of injection water	Measurement taken on sample of injection water used in test.
Surface tension of injection water	Measurement taken on sample of injection water used in test
Solids in injection water	Measurement taken on sample of injection water used in test.
Element physical parameters	
Element weight (initial)	Pre-test weight, g
Element ΔP in trough	Differential pressure in trough, psi
Element ΔP at 0 min	Differential pressure at start of test, psi
Element performance parameters	
Element weight gain	(Post-test dried weight)-(pre-test weight), g
% dirt load at 20 psi	Based on calculated amount of injected solids and element rated capacity of 200g.
% dirt load at 40 psi	Based on calculated amount of injected solids and element rated capacity of 200g.
Average AEL*	Average of all measurements after start of water injection, mg/ℓ, up to 40 psi.
Maximum AEL* rating	Maximum of all measurements after start of water injection, mg/ℓ, up to 40 psi.
AEL* rating of sample A	Value obtained at following times: Procedure 10: 95 min; Procedure 8901B, modified inhibitor fuel test: 65 min; all other procedures: 5 min.
AEL* rating of sample B	Value obtained at following times: Procedure 8901B, modified inhibitor fuel test: 80 min; all other procedures: 20 psi.
AEL* rating of sample C	Value obtained at following times: Procedure 8901B, modified inhibitor fuel test: 90 min; all other procedures: 40 psi.

TABLE 16. LISTING OF TEST DATA USED IN COMPUTER ANALYSES (Cont'd)

Datum	Description
Average solids content	Average of all measurements after start of solids injection, mg/ℓ, up to 40 psi.
Maximum solids content	Maximum of all measurements after start of solids injection, mg/ℓ, up to 40 psi.
Solids in sample A	Value obtained when drawing corresponding AEL sample.
Solids in sample B	Value obtained when drawing corresponding AEL sample.
Solids in sample C	Value obtained when drawing corresponding AEL sample.
Average Totamitor rating	Average of all measurements taken after element had been exposed to water or solids.
Maximum Totamitor rating	Maximum of all measurements after start of either water or solids injection, up to 40 psi.
Totamitor at sample A	Value obtained when drawing corresponding AEL sample.
Totamitor at sample B	Value obtained when drawing corresponding AEL sample.
Totamitor at sample C	Value obtained when drawing corresponding AEL sample.

*AEL ratings determined on 500-ml samples. Ratings have not been corrected for sample volume.

The "element weight gain" represents the amount of solids retained during the entire test. If retention is efficient, and if the dirt feeder is operating properly, the weight gain corresponds closely to the "calculated" dirt injection. The calculated values, based on dirt feeder calibration, are used to obtain the "dirt loads at 20 and 40 psi," expressed as percentages of the nominal dirt capacity of 200 g. The measured "weight gain" refers to the entire test, not to any given pressure differential, and hence does not necessarily correspond to a calculated value for 20 or 40 psi even if retention is total and the dirt feeder calibration is perfect.

The samples designated A, B, and C (Table 15) are effluent fuel samples chosen arbitrarily to give the maximum number of comparable data points for each procedure.

4. Statistics and Computor Program

All computer programming was performed by personnel of the Directorate of Computation Services, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Computations were made on that organization's IBM 7090/7094 direct-coupled system. Fortran IV language was used.

Three types of statistical information were derived from the computer program. Minimum, maximum, mean, and standard deviation of the various parameters were extracted or computed for test groupings according to different combinations of test conditions. A special program was written for storing and retrieving data and the computer output was obtained by means of the TALLY subroutine (slightly altered).

The second type of computer output consisted of parameter means and standard deviations for tests grouped according to various combinations of test conditions and also, the calculated value of ***Student's t*** for pairs of test groupings. These calculations were performed by means of the TTEST subroutine. An example of this output is as

follows: mean and standard deviation of element weights for each element lot are calculated and then *Student's t* is calculated for different pairs of element lots. *Student's t* can be used to assign levels of significance to the difference of means of two groups of data. This last operation was performed manually using published significance tables[8].

The third type of computer output consisted of regression coefficients and equations and correlation coefficients for pairs of parameters from tests grouped according to various combinations of test conditions. A typical example of this type of output is the regression and correlation coefficients for element weight versus element differential pressure for groups of tests having the same element lot and fuel. The regression and correlation calculations were performed by means of the MISR subroutine (slightly altered). Additional output from this subroutine includes means, standard deviations, skewness, kurtosis, and standard errors of regression coefficients.

In addition to the foregoing computer programs, a program was written to compute the t statistic used in determining the significance of the difference between two regression coefficients. The equations used in the computer calculations are given below.

Standard deviation(SD)

$$SD = \sqrt{\frac{\Sigma (X - \overline{X})^2}{n - 1}}$$

where

X = individual parameter value

$\overline{X}$ = mean of all parameter values

n = number of parameter values

Student's t for difference of means

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{(SD_1)^2}{n_1} + \frac{(SD_2)^2}{n_2}}}$$

where $\overline{X}_1$ and $\overline{X}_2$ are means of parameters for data groups 1 and 2, SD_1 and SD_2 are standard deviations of parameters for data groups 1 and 2, and n_1 and n_2 are number of parameter values in data groups 1 and 2.

Regression coefficient (b)

$$b = \frac{\Sigma\,[(X - \overline{X})(Y - \overline{Y})]}{\Sigma\,(X - \overline{X})^2}$$

where X and Y are individual parameter values.

The regression coefficient appears in the equation for the regression line as follows:

$$Y = bX + a$$

where a is the Y-intercept of the line (a is provided in the computer output).

The above two equations refer to the line of regression of Y on X, i.e., the best least-squares fit to minimize deviations from the line in the Y-direction. In accordance with customary usage, X is the independent and Y the dependent variable.

Correlation coefficient (r)

$$r = b\sqrt{\frac{\Sigma (X - \bar{X})^2}{\Sigma (Y - \bar{Y})^2}}$$

Correlation coefficients provide a measure of the scatter of data about the regression line. Correlation coefficients may range from −1 to +1 and will have the same sign as the regression coefficient. A value of zero denotes no correlation and a value of unity denotes perfect correlation (all points on the line). The significance of intermediate values depends upon the number of degrees of freedom (n − 2).

Statistical significance is stated in terms of the probability (percent) that a greater correlation coefficient would be obtained by chance in infinite samplings of the same population. Levels of significance of correlation coefficients reported herein were obtained from Reference (8).

Student's t for difference between regression coefficients

The level of significance of differences in regression coefficients was assigned by first calculating the t statistic and then determining the level of significance from a table relating t values to probability of chance occurrence of greater differences[8]. The equation[9] for calculating t is given below:

$$t = \frac{b_1 - b_2}{\sqrt{\frac{(n_1 - 1)(S_{y_1}^2 - b_1^2 S_{x_1}^2) + (n_2 - 1)(S_{y_2}^2 - b_2^2 S_{x_2}^2)}{n_1 + n_2 - 4}\left[\frac{1}{(n_1 - 1) S_{x_1}^2} + \frac{1}{(n_2 - 1) S_{x_2}^2}\right]}}$$

where b_1, b_2 are regression coefficients; n_1, n_2 are number of data in each set: and S_{x_1}, S_{x_2}, are standard deviations.

The significance level of various statistics is stated as the percent probability (P) that a greater difference in means, a greater correlation coefficient, or a greater difference in regression coefficients could have occurred by chance. For example, if a correlation coefficient is significant at the 5% level, a larger correlation coefficient would occur by chance 5% of the time in an infinite number of samplings on the same population. It should be emphasized that smaller probabilities indicate greater significance. For example, customary designations of significance levels are as follows:

Significant:	Probability less than 5%
Highly significant:	Probability less than 1%
Very highly significant:	Probability less than 0.1%

5. Fuel Quality Parameters

a Typical Levels of Fuel Quality Parameters

Two fuel quality parameters (WSIM and IFT) were measured in most of the Al/SS loop tests. Generally, each parameter was measured on samples taken at the following times: post-clay treatment, pre-test (after blending with additives), and post-test.

Mean pre-test WSIM values for four different JP-4 blends are given in Table 17. The number of measurements is three or less in every case and neither the accuracy nor precision can be considered as very reliable.

The uniformity of WSIM levels for clay-treated JP-5 is shown by the results on three fuel batches given in Table 18. Fuel batches 23 and 24 had mean post-clay WSIM values which were very close, 96.5 and 96.4, respectively. The mean post-clay WSIM value for batch 25 (98.4) was significantly different ($P < 1\%$) than those obtained for either batches 23 or 24.

Table 19 contains mean pre-test WSIM data for a variety of JP-5 fuel blends including both clay-treated and untreated fuel. Also, mean post-test WSIM data are given for all of the clay-treated fuel blends except for uninhibited JP-5.

As part of the later WSIM tests on JP-5 the size (diameter) and color of the stain on the WSIM disks was recorded. Mean size and color ratings for clay-treated JP-5 of three different batches are given in Table 20.

None of the fuel batches exhibited either mean WSIM stain size or stain color that was significantly different from either of the other two batches.

WSIM disk stain size and color rating data for pre-test and post-test measurements on a variety of JP-5 fuel blends are given in Table 21. Considering first the results from tests involving JP-5 which had not been clay-treated, there is considerable variation in both the mean stain size and color rating for the various fuel blends. The limited number of replicate tests precludes any attempt to det[illegible] significant differences in the WSIM-disk staining characteristics of the fuel blends.

Results from tests on clay-treated JP-5 are given in the lower half of Table 21. The level of both stain size and

TABLE 17. PRE-TEST WSIM DATA FOR JP-4 FUEL BLENDS

Fuel blend	Pre-test WSIM		
	No. of measurements	Mean	SD
JP-4	2	100.0	0
JP-4 + 0.15% FSII	3	93.7	9.29
JP-4 + 1.0 mg/ℓ ASA + 0.10% FSII	3	91.0	5.57
JP-4 + 4 lb/Mbbl AFA + 1.0 mg/ℓ ASA + 0.10% FSII	3	72.0	6.73

TABLE 18. POST-CLAY TREATMENT WSIM DATA FOR JP-5 FUEL BATCHES

Fuel batch	Post-clay WSIM		
	No. of tests*	Mean	SD
23	33	96.5	2.31
24	49	96.4	2.47
25	16	98.4	1.86

*Includes only tests in which post-clay treatment WSIM measurements were taken.

TABLE 19. PRE-TEST AND POST-TEST WSIM DATA FOR JP-5 FUEL BLENDS

Corr inhib	Concn, lb/Mbbl	FSII, vol %	Pre-test WSIM			Procedure	Post-test WSIM		
			No. of Measurements	Mean	SD		No. of Measurements	Mean	SD
Untreated JP-5									
none	--	0.00	2	83.5	12.0	...	...	...	...
none	---	0.15	6	87.0	6.0	...	...	...	...
Snt	4	0.15	4	71.2	7.9	...	...	...	...
Snt	16	0.00	3	71.7	13.0	...	...	...	...
Snt	16	0.15	34	71.1	9.7	...	...	...	...
AFA	4	0.10	5	42.2	8.6	...	...	...	...
AFA	4	0.15	4	62.2	4.5	...	...	...	...
AFA	16	0.15	21	60.9	10.0	...	...	...	...
Tol	20	0.15	4	30.0	1.8	...	...	...	...
Lubr	20	0.15	3	42.3	3.2	...	...	...	...
RP	20	0.15	18	42.3	8.9	...	...	...	...
EDS	14.5	0.15	4	11.0	00.8	...	...	...	...
Uni	9	0.15	5	59.8	12.3	...	...	...	...
Uni	20	0.15		31.3	6.3	...	...	...	...
Clay-treated JP-5									
none	...	0.00	2	97.5	2.1	...	...	...	
						13-J	5	76.2	8.6
Snt	16	0.15	29	72.6	11.1	13-A	17	72.5	7.6
Snt	16	0.15	...		...	13-P	3	93.3	2.5
AFA	10	0.15	4	71.8	7.6	*	4	84.5	9.5
AFA	16	0.15	23	71.8	8.5	13-A	21	71.1	9.9
Lubr	20	0.15	25	63.6	10.9	13-A	23	64.0	9.5
RP	20	0.15	9	64.8	8.9	13-A	8	66.5	10.3
Uni	20	0.15	3	34.7	1.5	13-A	3	35.7	4.7

*Modified 89018 inhibited fuel test.

TABLE 20. WSIM DISK STAIN SIZE AND COLOR FOR CLAY-TREATED JP-5

JP-5 batch no.	WSIM disk stain diameter, 16th in.			WSIM disk stain color*		
	No. of tests	Mean	SD	No. of tests	Mean	SD
23	33	3.2	2.7	33	0.9	0.8
24	47	3.6	2.5	47	1.1	0.8
25	15	2.7	2.8	15	0.7	0.8

*Color rating scale: 0 = none; 1 = light; 2 = medium; 3 = dark.

stain color for tests on clay-treated JP-5 are much less than corresponding values for tests on untreated JP-5. These results conclusively demonstrate that clay treating removes some stain-producing constituents from the fuel. Wear debris from the separometer pump is another source of staining. The amount of staining caused by wear debris will tend to decrease with increased lubricity of the fuel. The lesser staining propensity of the clay-treated fuel implies that lack of lubricity is not the sole factor contributing to staining, for if it were, clay-treated fuel would produce as much stain as untreated fuel. However, in some cases, lack of lubricity may be a significant factor in stain production. For example, both stain size and color are significantly less for fuel blends containing Lubrizol 541 than for fuel blends containing either Santolene C or AFA-1. These differences may be attributable to differences in either lubricity or concentration of stain-producing constituents as effected by the different corrosion inhibitors.

TABLE 21. WSIM DISK STAIN DATA FOR JP-5 FUEL BLENDS

JP-5 fuel blend			No. of tests	Pre-test WSIM disk stain,				No. of tests	Procedure	Post-test WSIM disk stain,			
				Diameter, 16th in.		Color rating*				Diameter, 16th in.		Color rating*	
Corr inhib	Concn, lb/Mbbl	FSII, %		Mean	SD	Mean	SD			Mean	SD	Mean	SD
Untreated JP-5													
Snt	4	0.15	3	6.7	1.1	1.7	0.6	---	--	---	---	---	---
Snt	16	0.15	7	6.4	1.6	2.1	0.4	---	---	---	---	---	---
AFA	4	0.10	5	5.8	0.4	1.2	0.4	---	---	---	---	---	---
AFA	4	0.15	3	6.0	0.0	2.0	0	---	---	---	---	---	---
AFA	16	0.15	6	4.7	2.1	1.7	1.0	---	---	---	---	---	---
RP	20	0.15	6	3.3	1.2	1.0	0	---	---	---	---	---	---
Uni	9	0.15	4	7.2	1.0	1.0	0	---	---	---	---	---	---
Uni	20	0.15	4	3.8	3.3	0.8	0.5	---	---	---	---	---	---
Clay-treated JP-5													
Snt	16	0.15	28	1.9	2.5	0.6	0.9	16	13A	3.1	2.4	0.8	0.7
								5	13J	0	0	0	0
AFA	10	0.15	4	1.0	2.0	0.2	0.5	4	8901B‡	0	0	---	---
AFA	16	0.15	23	2.1	2.0	0.6	0.5	21	13A	0.6	1.4	0.2	0.4
Lubr	20	0.15	25	0.4	1.3	0.1	0.3	21	13A	0.6	1.3	0.2	0.5
RP	20	0.15	9	1.2	1.4	0.8	1.0	8	13A	0.5	0.9	0.2	0.5
Uni	20	0.15	3	1.3	2.3	0.3	0.6	3	13A	0	0	0	0

*Rating scale: 0 = none, 1 - light, 2 - medium, 3 = dark.
‡Modified 8901B inhibited fuel test.

Results in Table 21 also suggest that, during the course of a given filter-separator test, the stain-producing tendency of the fuel was decreased, as evidenced by generally lower color ratings and stain sizes for post-test WSIM disks than for pre-test WSIM disks. This reduction in staining could very well be attributed to the removal of stain-producing constituents either by entrainment in the coalesced water or by retention in the filter-separator element.

Post-clay treatment IFT data for JP-5 fuel of three different batches are given in Table 22. Batch 23 had a mean IFT value which is significantly less than that of either batch 24 or 25. A greater difference in means would occur by chance in less than 1% of an infinite number of samplings.

In Table 23, pre-test IFT data for JP-4 fuel blends, JP-5 fuel blends, and clay-treated JP-5 fuel blends are given along with post-test IFT data

TABLE 22. POST-CLAY TREATMENT IFT DATA FOR JP-5 FUEL BATCHES

Fuel batch	Post-clay treatment IFT		
	No. of tests*	Mean	SD
23	33	42.2	2.09
24	49	44.2	3.46
25	15	44.7	2.66

*Includes only tests in which measurements were taken.

TABLE 23. PRE-TEST AND POST-TEST IFT DATA FOR JP-4 AND JP-5 FUEL BLENDS

Fuel blend*			Pre-test IFT, dyn/cm			Procedure	Post-test IFT, dyn/cm		
Corr inhib	Concn, lb/Mbbl	FSII, vol %	No. of tests	Mean	SD		No. of tests	Mean	SD
Untreated									
none†	---	0.10	3	42.7	0.6	---	---	---	---
Snt‡	4	0.15	3	35.7	2.5	---	---	---	---
AFA†	4	0.10	3	26.3	1.5	---	---	---	---
none	---	0.15	6	43.8	1.5	---	---	---	---
Snt	4	0.15	4	38.8	2.6	---	---	---	---
Snt	16	0.00	4	36.5	1.3	11	3	40.0	1.0
Snt	16	0.15	34	34.9	2.7	---	---	---	---
AFA	4	0.10	5	33.6	1.1	---	---	---	---
AFA	4	0.15	4	33.2	1.0	---	---	---	---
AFA	16	0.15	21	23.3	1.2	---	---	---	---
Tol	20	0.15	4	25.2	1.0	---	---	---	---
Lubr	20	0.15	3	26.3	0.6	---	---	---	---
RP	20	0.15	18	27.1	0.7	---	---	---	---
EDS	14.5	0.15	4	13.5	1.7	---	---	---	---
Uni	9	0.15	5	32.0	4.8	---	---	---	---
Uni	20	0.15	7	23.7	5.6	---	---	---	---
Clay-treated									
Snt	16	0.15	29	36.1	2.2	13A	17	38.4	2.3
						13J	5	35.4	1.3
						13P	3	34.7	1.5
AFA	10	0.15	4	24.8	0.5	8901B**	4	25.8	0.5
AFA	16	0.15	23	22.4	0.9	13A	21	22.7	0.9
Lubr	20	0.15	25	25.6	1.6	13A	23	26.3	1.7
RP	20	0.15	9	26.8	1.2	13A	8	26.8	1.7
Uni	20	0.15	3	23.7	3.1	---	---	---	---

*JP-5 unless otherwise indicated. **Modified 8901B inhibited fuel test.
†JP-4 fuel blend, also included 1.0 mg/ℓ ASA.
‡JP-4 fuel blend.

for several JP-5 blends. The results indicate that there is no significant difference between IFT levels for fuel-corrosion inhibitor blends made with clay-treated or untreated JP-5. As would be expected, IFT decreased with increased corrosion inhibitor concentration for all the corrosion inhibitors which were used.

Both pre-test and post test IFT measurements were made on only six fuel blends. In the case of one fuel blend, clay-treated JP-5 + 16 lb/Mbbl Santolene C + 0.15% FSII, post-test IFT measurements include those from tests run according to three different procedures, thus making eight groups of post-test IFT measurements. In six of the eight groups, the mean post-test IFT is greater than the mean pre-test IFT. This suggests, but not conclusively, that the coalesced water removes some fuel constituents to effect an increase in IFT.

b. Variation in Fuel Quality Parameters with Water Washing

Almost all of the test procedures used in this work included injecting water into the fuel at one time or another during the test. Virtually all of this water is removed by the test filter-separator element which is consequently well permeated with water. Thus, the fuel passing through the element comes into contact with large surface areas of water, in addition to the extensive water-fuel contact occasioned by the mixing screen and the turbulent flow in the line up to the test filter-separator housing. The removal of water-soluble fuel constituents by the coalesced water could very possibly affect fuel composition or fuel quality parameters as follows: FSII concentration, post-test IFT, and post-test WSIM and related measurements, WSIM stain color, and size.

There appears to be a negative correlation between FSII concentration and the amount of water to which the fuel has been exposed during a test. Regression and correlation calculations were performed using fuel washing (total amount of injected water) as the independent variable and FSII content as the dependent variable. Results of these calculations are shown in Table 24. The greater solubility of FSII in water than in fuel would be expected to result in the removal of FSII along with the coalesced water. In five out of seven groups of tests, there was a significant negative correlation between post-test FSII concentration and water washing. The two cases of positive correlation are not significant. The overall degree of negative correlation is probably as good as can be expected, since the theoretical equation for FSII extraction in a closed-loop system is logarithmic rather than linear

TABLE 24. EFFECT OF WATER WASHING ON POST-TEST FSII CONCENTRATION

(Fuel: JP-5)

Additives	No. of tests	Regression equation*	Correlation coefficient: Value	Correlation coefficient: Signif level, %
Untreated				
16 lb/Mbbl Snt + 0.15% FSII	23	Y = 0.0005X + 0.01	0.19	>10
20 lb/Mbbl Lubr + 0.15% FSII	5	Y = −0.44X + 0.11	−0.99	<0.1
Clay-treated				
16 lb/Mbbl Snt + 0.15% FSII	27	Y = −0.002X + 0.09	−0.83	<0.1
10 lb/Mbbl AFA + 0.15% FSII	4	Y = −0.001X + 0.05	−1.00	<0.1
16 lb/Mbbl AFA + 0.15% FSII	23	Y = −0.010X + 0.13	−0.68	<0.1
20 lb/Mbbl Lubr + 0.15% FSII	25	Y = −0.010X + 0.14	−0.54	1.0
20 lb/Mbbl RP + 0.15% FSII	9	Y = 0.002X + 0.08	0.03	>10

*Y = FSII concentration; X = Fuel washing.

and includes the water injection ratio as well as the total amount of water injected. For this 600-gal system, assuming 100% extraction efficiency, a coefficient of 200 for distribution of FSII between water and fuel phases, and uniform FSII concentration in the supply tank, the equation is

$$\log C/C_o = \frac{-W}{6.9\,(1 + 200\,R)}$$

where

C = final concentration of FSII

C_c = initial concentration of FSII

W = total water injected, gal

R = injection ratio (water/fuel rate ratio)

The validity of this theoretical equation has been confirmed for specific cases, but no statistical tests have been made.

There appears to be slight correlation between post-test IFT and water washing. Although five out of seven correlations are positive (see Table 25), only two are statistically significant.

Post-test WSIM appears to increase with increased water washing, as evidenced by five positive correlation coefficients (four of which are statistically significant) out of seven, as shown in Table 26.

There appears to be no significant correlation between either WSIM stain color and size and water washing, see Tables 27 and 28.

TABLE 25. EFFECT OF WATER WASHING ON POST-TEST IFT

(Fuel: JP-5)

Additives	No. of tests	Regression equation*	Correlation coefficient	
			Value	Signif level, %
Untreated				
Pt L	5	Y = 0.20X + 39.8	0.15	>10
PtCr	8	Y = –0.75X + 46.6	–0.44	>10
NA-1	4	Y = –0.26X + 53.9	–0.79	>10
Clay-treated				
16 lb/Mbbl Snt + 0.15% FSII	29	Y = 0.12X + 37.1	0.41	2-5
10 lb/Mbbl AFA + 0.15% FSII	4	Y = 0.06X + 24.5	0.56	>10
16 lb/Mbbl AFA + 0.15% FSII	23	Y = 0.49X + 21.0	0.45	2-5
20 lb/Mbbl Lubr + 0.15% FSII	25	Y = 0.63X + 25.8	0.25	>10

*Y = Post-test IFT; X = Water washing.

TABLE 26. EFFECT OF WATER WASHING ON POST-TEST WSIM

(Fuel: JP-5)

Additives	No. of tests	Regression equation*	Correlation coefficient Value	Signif level, %
Untreated				
Pt L	5	Y = 0.10X + 47.5	0.89	2-5
Pt CR	8	Y = 0.38X + 67.5	0.80	1-2
NA-1	4	Y = 0.50X + 64.1	0.67	>10
Clay-treated				
16 lb/Mbbl Snt + 0.15% FSII	29	Y = 0.49X + 75.8	0.40	2-5
10 lb/Mbbl AFA + 0.15% FSII	4	Y = 0.18X + 45.0	0.98	0.1-1
16 lb/Mbbl AFA + 0.15% FSII	23	Y = -0.46X + 87.1	-0.40	5-10
20 lb/Mbbl Lubr + 0.15% FSII	25	Y = -0.64X + 70.0	-0.40	5

*Y = Post-test WSIM, X = Water washing.

TABLE 27. EFFECT OF WATER WASHING ON POST-TEST WSIM STAIN COLOR

(Fuel: JP-5)

Additives	No. of tests	Regression equation*	Correlation coefficient Value	Signif level, %
Untreated				
Pt CR	8	Y = 0.03X + 0.96	0.20	>10
NA-1	4	Y = -0.10X + 0.02	-0.15	>10
Clay-treated				
16 lb/Mbbl Snt + 0.15% FSII	29	Y = 0.15X + 0.47	0.22	>10
16 lb/Mbbl AFA + 0.15% FSII	23	Y = 0.07X - 0.61	0.18	>10
20 lb/Mbbl Lubr + 0.15% FSII	25	Y = -0.17X + 0.38	-0.22	>10
20 lb/Mbbl RP + 0.15% FSII	9	Y = -0.59X + 0.22	-0.33	>10

*Y = Post-test WSIM stain color, X = Water washing.

TABLE 28. EFFECT OF WATER WASHING ON POST-TEST WSIM STAIN SIZE

(Fuel: JP-5)

Additives	No. of tests	Regression equation*	Correlation coefficient Value	Signif level, %
Untreated				
Pt CR	8	Y = 0.51X + 3.90	0.55	>10
NA-1	4	Y = 0.67X + 4.05	0.97	2-5
Clay-treated				
16 lb/Mbbl Snt + 0.15% FSII	29	Y = 0.12X + 1.59	0.45	1-2
16 lb/Mbbl AFA + 0.15% FSII	23	Y = 0.24X - 0.20	0.16	>10
20 lb/Mbbl Lubr + 0.15% FSII	25	Y = -0.45X + 0.93	-0.23	>10
20 lb/Mbbl RP + 0.15% FSII	9	Y = 0.002X + 0.08	0.33	>10

*Y = Post-test WSIM stain size, X = Water washing.

c. **Correlation Between Fuel Quality Parameters and Element Performance Parameters**

Knowledge of the correlation between fuel quality parameters, WSIM and IFT, and the various parameters of element performance would prove very useful for predicting performance of filter-separator elements both in testing and in field applications. Relations between the fuel quality and element performance parameters were sought by means of regression and correlation calculations on groups of tests on JP-5 fuel; each group consisted of tests having the same corrosion inhibitor corrosion inhibitor concentration, and FSII concentration, and were run on the same lot of elements; see Table 29.

The results of these calculations are rather surprising. Correlation was generally poor, and, where slight correlation was suggested, the correlation was in nearly all cases of opposite sign to what would be logically expected. The overall implication of these calculations is summarized in Table 30. The extent of correlation was assigned on the following basis: slight positive correlation where 11 or more of the 19 correlation coefficients were positive, slight negative correlation where 11 or more of the correlation coefficients were negative, and no correlation in cases where less than 11 correlation coefficients had the same sign.

The implied correlations between pre-test WSIM and the nine performance parameters in Table 30 is in every case opposite to what would be expected. For example, if the WSIM is an indicator of fuel performance in filter-separators, the percent dirt load at 20 and at 40 psi would be expected to increase with increasing pre-test WSIM, and the remaining performance parameters should decrease with increasing WSIM. However, all implied correlations were of the opposite sign. Much the same situation exists for correlations between pre-test IFT and performance parameters for these groups of tests, except that in five cases no correlation was indicated.

The slight extent of correlation indicated by the foregoing calculations is best illustrated by the calculated results shown in Table 31 for the combination of pre-test WSIM vs average Totamitor, which exhibited the best overall correlation. In most cases, the correlation coefficients are not significant even at the 10% level. The few cases in which high levels of significance were indicated may be fortuitous, since there are both positive and negative statistically significant correlations, also, there are cases where both positive and negative correlations were obtained for the same fuel blends, such as clay-treated fuel containing 16 lb/Mbbl Santolene C tested with different element lots.

TABLE 29. FUEL BLENDS AND ELEMENTS USED IN CALCULATING CORRELATIONS BETWEEN WSIM AND ELEMENT PERFORMANCE PARAMETERS

*(Fuel: JP-5)**

Corr inhib	Concn, lb/Mbbl	FSII, %	Element	No. of Tests
Untreated				
Sntt†	16	0.15	FI 256	15
Sntt†	16	0.15	FI 440	9
AFA	4	0.10	FI 465	5
RP	20	0.15	FI 465	4
Clay-treated				
Snt	16	0.15	FI 465	5
Snt	16	0.15	Fr	4
Snt	16	0.15	Bn	4
Snt	16	0.15	Bw	4
AFA	16	0.15	FI 465	9
AFA	16	0.15	Fr	4
AFA	16	0.15	Bn	4
AFA	16	0.15	Bw	4
Lubr	20	0.15	FI 465	7
Lubr	20	0.15	FI GS	4
Lubr	20	0.15	Fr	4
Lubr	20	0.15	Bn	4
Lubr	20	0.15	Bw	4
RP	20	0.15	FI 465	9
Snt‡	16	0.15	FI 465	5

*Tested according to Procedure 13-A, unless otherwise noted
†Procedure 10.
‡Procedure 13-J.

TABLE 30. CORRELATIONS BETWEEN PRE-TEST WSIM AND IFT AND ELEMENT PERFORMANCE PARAMETERS

Performance parameter	Extent of correlations*	
	Pre-test WSIM	Pre-test IFT
Element weight gain		
% Dirt load at 20 psi		0
% Dirt load at 40 psi	[illegible]	0
Average AFI rating	+	+
Maximum AFI rating	+	+
Average solids content	+	0
Maximum solids content	+	0
Average Totamitor	+	0
Maximum Totamitor	+	+

*0 indicates no correlation, – indicates slight negative correlation, + indicates slight positive correlation.

TABLE 31. PRE-TEST WSIM VS AVERAGE TOTAMITOR READING

*(Fuel: JP-5)**

Corr inhib	Concn, lb/Mbbl	FSII, vol %	Element Identification	No. of tests	Correlation Coefficient	
					Value	Signif level, %
Untreated						
Snt†	16	0.15	FI 286	15	0.06	>10
Snt†	16	0.15	FI 440	9	---	---
AFA	4	0.10	FI 465	5	0.96	1
RP	20	0.15	FI 465	4	0.90	10
Clay-treated						
Snt	16	0.15	FI 465	5	0.71	>10
Snt	16	0.15	Fr	4	−0.39	>10
Snt	16	0.15	Bn	4	---	---
Snt	16	0.15	Bw	4	0.82	>10
AFA	16	0.15	FI 465	9	0.25	>10
AFA	16	0.15	Fr	4	0.85	>10
AFA	16	0.15	Bn	4	---	---
AFA	16	0.15	Bw	4	0.28	>10
Lubr	20	0.15	FI 465	7	−0.85	1-2
Lubr	20	0.15	FI GS	4	0.57	>10
Lubr	20	0.15	Fr	4	0.52	>10
Lubr	20	0.15	Bn	4	0.63	>10
Lubr	20	0.15	Bw	4	0.18	>10
RP	20	0.15	FI 465	9	−0.17	>10
Snt‡	16	0.15	FI 465	5	0.00	>10

*Tested according to Procedure 13-A unless otherwise noted.
†Procedure 10.
‡Procedure 13-J

These disappointing results confirm earlier, qualitative observations that fuel WSIM or IFT cannot be used for reliable predictions of the fuel's performance in filter separators. This conclusion is subject to certain limitations in the statistical analysis; including (1) limited range of values of one or both parameters in many cases, (2) limited amount of data, and (3) scatter induced by variations in test conditions and materials. Nevertheless, the results of the analysis indicate rather strongly that further attempts at such correlations are unlikely to succeed and instead efforts should be directed toward development of entirely different test methods for correlative purposes.

Correlation for some of the same combinations of parameters was next sought using tests grouped only with respect to fuel (JP-4 or JP-5) and test procedure. Correlation of WSIM with four element performance parameters is shown in Table 32; now, the implied correlations are in nearly all cases of the same sign as would be expected. Correlation coefficients are generally not statistically significant. The plots of the regression lines in those cases where correlation is significant show general trends but should not be considered as highly quantitative. Using the same groups of tests, correlation between IFT and the same four element performance parameters was better than obtained in the more restrictive test groupings (see Table 33).

Plots of regression lines for five different fuel-procedure combinations are shown in Figure 4. In all cases, percent dirt load at 40 psi increased with pre-test WSIM. Because of the wide variety of additives and filter-separator element lots used in these tests, it would not be advisable to use these plots for quantitative prediction purposes.

An interesting set of plots is obtained when the regression lines for average solids content vs pre-test WSIM are plotted (see Figure 5). Regression lines are shown for tests run by different procedures on JP-4 and

TABLE 32. CORRELATION BETWEEN PRE-TEST WSIM AND ELEMENT PERFORMANCE PARAMETERS

Fuel	Procedure	No. of tests	Correlation coefficient between pre-test WSIM and indicated parameter							
			% dirt at 40 psi		Avg AEL rating, mg/ℓ		Avg solids content, mg/ℓ		Avg Totamitor	
			Value	Signif level, %	Value	Signif level, %	Value	Signif level, %	Value	Signif level, %
Untreated										
JP-4	10	16	0.80	<0.1	-0.23	>10	-0.01	>10	-0.10	>10
JP-4	13-A	8	0.69	5-10	-0.75	2-5	-0.67	5-10	-0.17	>10
JP-5	*	6	---	---	-0.91	1-2	-0.32	>10	-0.75	5-10
JP-5	10	37	-0.03	>10	-0.69	<0.1	-0.36	2-5	-0.65	<0.1
JP-5	13-N	10	0.20	>10	0.15	>10	0.36	>10	0.20	>10
JP-5	13-O	10	0.23	>10	0.04	>10	-0.42	>10	-0.24	>10
JP-5	14-A	5	0.32	>10	-0.04	>10	-0.67	>10	-0.76	>10
Clay-treated										
JP-5	13-A	118	0.37	<0.1	-0.14	>10	-0.18	5-10	-0.28	0.1-1
JP-5	13-J	30	0.37	2-5	-0.38	2-5	-0.47	0.1-1	-0.54	0.1-1
JP-5	13-P	8	0.65	5-10	0.02	>10	-0.72	2-5	0.18	>10

*Modified 8901B inhibited fuel test.

TABLE 33. CORRELATION BETWEEN PRE-TEST IFT AND ELEMENT PERFORMANCE PARAMETERS

Fuel	Procedure	No. of tests	Correlation coefficient between pre-test IFT and indicated parameter							
			% dirt at 40 psi		Avg AEL rating, mg/ℓ		Avg solids content, mg/ℓ		Avg Totamitor	
			Value	Signif level, %	Value	Signif level, %	Value	Signif level, %	Value	Signif level, %
Untreated										
JP-4	10	16	0.19	>10	-0.70	0.1-1	0.22	>10	0.32	>10
JP-4	13-A	8	0.96	<0.1	-0.15	>10	0.70	2-5	0.01	>10
JP-5	*	6	---	---	0.91	0.1-1	0.65	>10	0.90	0.1-1
JP-5	10	37	0.05	>10	0.61	<0.1	0.19	>10	0.60	<0.1
JP-5	13-N	10	0.41	>10	0.43	>10	0.29	>10	0.23	>10
JP-5	13-O	10	0.02	>10	0.17	>10	0.35	>10	0.17	>10
JP-5	14-A	5	0.24	>10	0.53	>10	0.51	>10	0.51	>10
Clay-treated										
JP-5	13-A	118	0.17	5-10	0.19	2-5	0.18	2-5	0.02	>10
JP-5	13-J	30	0.53	0.1-1	0.63	<0.1	0.49	0.1-1	0.65	<0.1
JP-5	13-P	8	0.82	0.1-1	-0.29	>10	0.55	>10	0.13	>10

*Modified 8901B inhibited fuel test.

JP-5 fuels containing a number of different additives. Again, because of the diversity in fuel blends and elements, little quantitative significance can be ascribed to these plots. However, the locations and slopes of the lines are consistent with the differences in particle size of the contaminants and the differences in procedures. The coarsest contaminant (coarse AC dust) is used in Procedures 10 and 13-A. Results from tests run according to these procedures show that, over a wide range of WSIM values, average effluent solids contents are generally well below those of tests run using finer contaminants, fine AC dust (Procedure 13-J) and ground iron ore (Procedure 13-P). It is interesting that the regression lines for Procedure 13-A run with either JP-4 or JP-5 are nearly coincident. The much lower average effluent solids contents in the Procedure 10 tests may be the result of the differences between that procedure and the other three procedures. In Procedure 10, the elements are subjected to extensive water washing before solids injection is started. In the other three procedures, the test element is loaded with solids before any large amount of water is injected. These three procedures are identical except for the solid contaminant. The fineness of the contaminant gave a regular effect on the WSIM-solids relationship: (1) the finest material (fine AC dust, Procedure 13-J) gave the greatest slope of the solids/WSIM line, (2) the coarsest material (coarse AC dust, Procedure 13-A) gave the smallest slope, and (3) the ground iron ore (Procedure 13-P) gave an intermediate slope. Thus, there is a regular relationship between contaminant particle size and the contaminant's tendency to pass through a filter-separator when the fuel quality is poor.

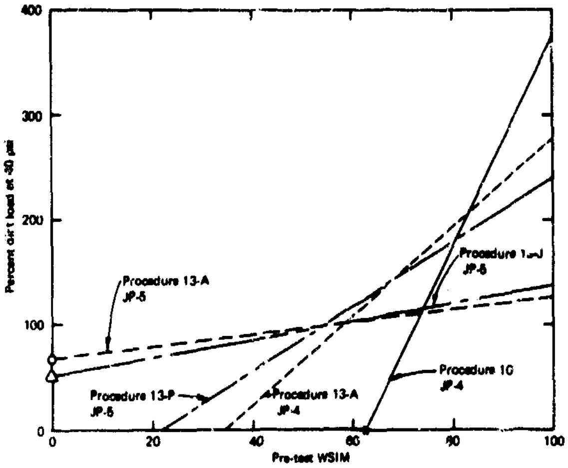

FIGURE 4. PERCENT DIRT LOAD AT 40 PSI VS PRE-TEST WSIM

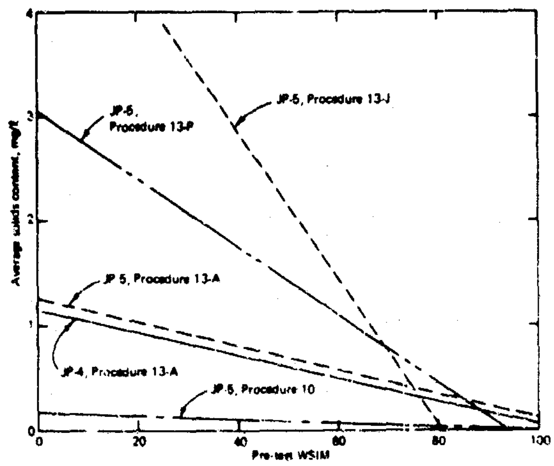

FIGURE 5. AVERAGE EFFLUENT SOLIDS CONTENT VS PRE-TEST WSIM

Although positive correlation between WSIM and IFT measurements is plausible, no significant correlation was indicated by the values of calculated correlation coefficients using either pre-test or post-test samples (see Tables 34 and 35). Comparable numbers of positive and negative correlation coefficients were obtained, and in only a few cases were the correlation coefficients great enough to imply statistical significance. In every case, the high levels of significance occurred for groups of five or less tests. It is very possible that the high levels of significance are fortuitous. The lack of correlation probably results from the small range of WSIM and IFT values associated with each group of tests.

The ranges of both WSIM and IFT values can be greatly increased by adding to each group the measurements from uninhibited fuel tests. Results of calculations on these regroupings are shown in Table 36. Using the relaxed test conditions, positive correlation coefficients were obtained for all nine groups of tests given. Also, in seven cases, the correlation coefficients are significant at better than the 1% level. In the other three cases, level of significance is worse than the 5% level. It is interesting that all the regression coefficients fall in the range of 0.1 to 0.4. It appears that regression equations, not necessarily linear, useful for correlating WSIM and IFT values could be obtained for each fuel-additive system by conducting replicate WSIM and IFT measurements at several concentrations ranging from zero to the maximum allowable additive concentration.

TABLE 34. CORRELATION BETWEEN PRE-TEST WSIM AND PRE-TEST IFT

Fuel	Corr inhib	FSII, vol %	No. of tests	Correlation coefficient	
				Value	Signif level, %
Untreated					
JP-4	none	0.15	5	-0.99	<0.1
JP-4	Snt	0.15	5	0.95	0.1-1
JP-4	AFA	0.10	5	0.75	5-10
JP-5	none	0	26	-0.04	>10
JP-5	none	0.15	6	0.11	>10
JP-5	Snt	0	4	-0.73	>10
JP-5	Snt	0.15	39	0.01	>10
JP-5	Snt	0.10	5	0.04	>10
JP-5	AFA	0.15	25	-0.04	>10
JP-5	Tol	0.15	6	0.97	<0.1
JP-5	Lubr	0.15	4	0.93	5-10
JP-5	RP	0.15	20	0.03	>10
JP-5	EDS	0.15	4	0.00	>10
JP-5	Uni	0.15	12	0.80	0.1-1
Clay-treated					
JP-5	Snt	0.15	29	-0.21	>10
JP-5	AFA	0.15	27	-0.03	>10
JP-5	Lubr	0.15	25	-0.38	>10
JP-5	RP	0.15	9	0.41	>10

TABLE 35. CORRELATION BETWEEN POST-TEST WSIM AND POST-TEST IFT

Fuel	Corr inhib	FSII vol %	No. of tests	Correlation coefficient	
				Value	Signif level, %
Untreated					
JP-4	none	0.15	5	---	---
JP-4	Snt	0.15	5	---	---
JP-4	AFA	0.10	5	---	---
JP-5	none	0	26	0.14	>10
JP-5	none	0.15	6	---	---
JP-5	Snt	0	4	---	---
JP-5	Snt	0.15	39	---	---
JP-5	Snt	0.10	5	---	---
JP-5	AFA	0.15	25	---	---
JP-5	Tol	0.15	6	---	---
JP-5	Lubr	0.15	4	---	---
JP-5	RP	0.15	20	---	---
JP-5	EDS	0.15	4	---	---
JP-5	Uni	0.15	12	---	---
Clay-treated					
JP-5	Snt	0.15	29	-0.13	>10
JP-5	AFA	0.15	27	0.14	>10
JP-5	Lubr	0.15	25	-0.25	>10
JP-5	RP	0.15	9	0.15	>10

TABLE 36. CORRELATION BETWEEN PRE-TEST WSIM AND PRE-TEST IFT FOR DIFFERENT CONCENTRATIONS OF CORROSION INHIBITORS INCLUDING ZERO CONCENTRATION

Fuel	Corr inhib	FSII, vol %	No. of tests	Regression equation	Correlation coefficient	
					Value	Signif level, %
JP-4	AFA	0.10	8	I = 0.4W + 2.6	0.62	5-10
JP-4	Snt	0.15	7	I = 0.3W + 6.2	0.59	>10
JP-5	Snt	0.00	27	I = 0.1W + 36.3	0.26	>10
JP-5	Snt	0.15	76	I = 0.1W + 29.1	0.31	0.1-1
JP-5	AFA	0.15	60	I = 0.3W + 4.3	0.52	<0.1
JP-5	Tol	0.15	16	I = 0.3W + 16.6	0.98	<0.1
JP-5	Lubr	0.15	37	I = 0.3W + 8.0	0.66	<0.1
JP-5	RP	0.15	37	I = 0.3W + 15.0	0.78	<0.1
[illegible]	EDS	0.15	12	I = 0.4W + 9.5	0.99	<0.1
	Uni	0.15	23	I = 0.4W + 12.1	0.94	<0.1

6. Clay Treatment Effects

a. Effect on Fuel Quality Parameters

(1) Effect on WSIM and IFT

Clay treatment caused an increase in WSIM of uninhibited JP-5 base fuel. Also, blends of any one of six corrosion inhibitors in the treated base fuel gave higher WSIM values than the corresponding blends with untreated base fuel. This is illustrated in Table 37. All seven compositions gave higher WSIM values with treated base fuel, indicating that the trend is highly significant, although some of the individual differences are not significant.

Based on the results given in Table 37, there was no significant difference in IFT of fuel blends made with clay-treated or untreated JP-5. IFT values of blends containing clay-treated JP-5 were higher than those of similar blends containing untreated JP-5 in three cases, less in three cases, and the same in one case.

Examination of post-clay treatment WSIM and IFT data from successive runs on the same clay canisters reveals that clay treating is more effective in restoring WSIM values to a high level than it is in restoring IFT values, particularly after a set of clay canisters has been used to treat a considerable volume of fuel. Data illustrating this effect are tabulated below:

Clay Treatment on New Canisters	Post-Clay Treatment WSIM and IFT values									
	Tests 248–255		Tests 261–272		Tests 273–288		Tests 289–301		Tests 304–313	
	WSIM	IFT	WSIM	IFT	WSIM	IFT	WSIM	IFT	WSIM	IFT
1	100	45.1	98	47.7	98	46.9	98	46.7	100	48.6
2	97	44.0	98	49.1	99	46.1	98	46.3	96	45.5
3	97	44.2	95	44.2	92	46.2	98	46.2	98	47.4
4	98	39.8	97	45.8	96	45.9	96	45.7	98	45.1
5	98	41.8	95	45.8	95	45.3	97	45.3	96	44.1
6	95	39.8	93	45.8	95	46.3	97	44.8	97	43.4
7	97	38.0	90	44.1	99	46.2	97	44.1	98	39.4
8	97	39.6	87	45.4	98	46.7	97	41.8	99	34.7
9			93	44.9	99	44.1	96	40.3	96	34.3
10			97	44.3	97	45.5	95	38.3	96	32.0
11			97	43.9	97	45.1	97	37.0		
12			93	42.6	96	44.6	98	44.7		
13					99	44.2	100	46.3		
14					97	44.3				
15					99	43.4				
16					94	43.1				

In all five series of clay treatments, WSIM values never decreased more than 8% from the value measured after the first clay treatment of fresh fuel, using new clay filter canisters. IFT values, however, decreased 8% to 34%.

The series of clay treatments starting with Test 289 is particularly interesting. WSIM values remained within the range of 95 to 98 during 13 clay treatments, but IFT values decreased sharply from 46.7 to a low of 37.0 after the eleventh clay treatment. No corrosion inhibitor was added to the fuel during the remaining three tests, and post-clay treatment IFT values increased from 37.0 to 46.3. The three tests involved here were special tests (299, 300A-D, and 301) involving extensive water injection. These results suggest that with increased usage the clay became less effective in removing corrosion inhibitors and this is reflected in decreasing IFT values. Also, it appears that repeated clay treatment of the fuel, without additions of corrosion inhibitor, removed these

traces of corrosion inhibitor. It is also quite possible that the extensive water washing of the fuel during the tests preceding the last two clay treatments played a role in increasing the IFT values.

Apart from effects of clay treating on the levels of the fuel quality parameters, it was thought likely that clay treating would affect the degree of scatter in the data. Examination of the standard deviations of WSIM and IFT measurements on fuel blends made up with both clay-treated and untreated JP-5 (see Table 37) indicates no trend towards either increasing or decreasing the standard deviation.

(2) Effect on FSII Concentration

An examination of FSII concentration data indicates that clay treatment does remove FSII from fuel, especially when the clay canister elements are new. Table 38 shows data from all the tests which were run immediately after fresh fuel treatment with new clay canisters. The differences between pre-clay treatment FSII concentrations*, and post-clay treatment FSII concentrations for the second through seventh use of the canisters with fuel are also shown. Just before clay treating, fuel was added to restore the fuel volume to 600 gal. Since the volume of makeup fuel was small (usually less than 30 gal), it would not cause an appreciable decrease in FSII concentration. The results of the first use of the canisters for fuel cleanup are not shown because in most cases the fuel treated was fresh from additive-free fuel storage and FSII concentration was not determined. The data show that the clay canisters remove less FSII with each succeeding treatment, removing essentially no FSII after about the sixth or seventh use. By statistical analysis, the difference in FSII concentration before and after clay treatment ranges from significant for the first treatment, to possibly significant for the sixth treatment.

The removal of FSII by clay treatment is by no means complete, as is believed to be the case with most commonly used corrosion inhibitors. As can be seen in Table 38, the average percent FSII removed from

TABLE 37. EFFECT OF CLAY TREATMENT ON QUALITY PARAMETERS OF JP-5 + VARIOUS CORROSION INHIBITORS

Corr inhib	Concn, lb/Mbbl	Fuel*	WSIM			IFT		
			Mean	Tests	SD	Mean	Tests	SD
none	0	NT	87.0	6	6.0	43.8	6	1.5
		CT	97.5	2	---	45.0	2	---
Snt	16	NT	71.1	34	9.7	34.9	34	2.7
		CT	72.6	29	11.1	36.1	29	2.2
AFA	16	NT	60.9	21	10.0	23.3	21	1.2
		CT	71.8	23	8.5	22.4	23	0.9
Tol	20	NT	30.0	4	1.8	25.2	4	1.0
		CT	36.0	2	---	28.5	2	---
Lubr	20	NT	42.3	3	3.2	26.3	3	0.6
		CT	63.6	25	10.9	25.6	25	1.6
RP	20	NT	42.3	18	8.9	27.1	18	0.7
		CT	64.8	9	8.9	26.8	9	1.2
Uni	20	NT	31.3	7	6.3	23.7	7	5.6
		CT	34.7	3	1.5	23.7	3	3.1

*NT is untreated JP-5; CT is clay-treated JP-5.

TABLE 38. EFFECT OF CLAY TREATMENT ON FSII CONCENTRATION

Test no.*	Change in FSII concentration with successive clay treatments					
	2nd	3rd	4th	5th	6th	7th
220	---	---	0.02	0.02	0.01	0.00
238	0.01	0.01	0.00	0.00	---	---
248	0.05	0.00	0.03	0.01	0.00	0.01
256	0.01	---	---	---	---	---
261	0.05	0.02	0.00	0.00	0.01	0.01
273	0.01	0.02	0.00	0.01	-0.01	0.01
289	0.06	0.03	0.02	0.01	0.01	0.01
304	0.06	0.01	0.01	0.00	0.01	0.01
314	0.00	0.06	0.03	0.01	0.00	0.01
325	0.02	0.03	0.02	---	---	---
328	0.00	---	---	---	---	---
Mean	0.023	0.018	0.010	0.008	0.004	0.006

*First test run after installation of new clay canisters.
†Each use involved treatment of a 600-gal volume of inhibited JP-5 until WSIM rating was 95 or higher. A positive value indicates an increase in FSII concentration; a negative value indicates a decrease.

*Post-test FSII concentration values from the preceding test were used to represent pre-clay treatment values.

TABLE 39. VARIATION OF FUEL COLOR IN SERIES OF TESTS WITH CLAY TREATING

Test no.	Additive	Concn, lb/Mbbl	Fuel color, Saybolt*		
			Post-clay treat	Pre-test	Post-test
289	Lubr	20	+30†‡	+30	+30
290	Lubr	20	+23	---	+23
291	Lubr	20	+22	+22	+21
292	Lubr	20	+21	+23	+22
293	Lubr	20	+23	+22	+21
294	Lubr	20	+22	+22	+21
295	Lubr	20	+22	+22	+21
296	Lubr	20	+22	+21	+21
297	Lubr	20	+20	+21	+21
298	Lubr	20	+21	+21	+21
299	none**	---	+21	+21	+22
300A	none**	---	+23	+23	+23
300B	none**	---	---	+24	+23
300C	none**	---	---	+24	+22
300D	none**	---	---	+23	+24
301	none**	---	+23	+23	+23
302	none**	---	---	+21	+22
303A	none**	---	---	+29	+29
303B	none**	---	---	+21	+21
304	Lubr	20	+30†‡	+30	+30
305	Lubr	20	+29	+28	+28
306	Lubr	20	+23	+28	+23
307	Lubr	20	+22	+23	+24
308	Lubr	20	+24	+26	+23
309	Lubr	20	+22	+23	+23
310	Lubr	20	+24	+23	+23
311	Lubr	20	+23	+22	+23
312	Lubr	20	+22	+22	+22
313	Lubr	20	+22	+21	+22
314	AFA	10	+30‡	+30	+30
315	AFA	16	+30	+30	+30
316	AFA	16	+27	+27	+27
317	Snt	16	+24	+24	+24
318	Snt	16	+23	+24	+24
319	none	---	+24	+23	+23
320	Snt	16	+23	+23	+23
321	Lubr	20	+23	+23	+23
322	Lubr	20	+23	+23	+23
323	Snt	16	+22	+22	+22
324	Snt	16	+22	+23	+22
325	AFA	10	+30‡	+30	+30
326	none	---	+30	+30	+30
327	AFA	10	+30	+30	+30
328	none	---	+28‡	+29	+28
329	AFA	10	+29	+29	+29

*Saybolt color rating of +30 represents the lightest color; −16 represents the darkest color.
†Color of uninhibited JP-5 fuel before clay treating was +19.
‡After installation of new clay cannisters.
**Test was run according to special procedure, contaminant was plug-valve grease.

the fuel with fresh canisters is only 0.02. However, on the basis of data obtained, the removal does appear to be real and significant. Although the mechanism of removal is not known, it is believed adsorption of FSII onto constituents of the clay occurs until all sites for such adsorption become saturated, and that the population of such sites is not as great as sites for corrosion inhibitor adsorption.

(3) Effect on Saybolt Color Ratings

In Table 39, the Saybolt color ratings of test fuels are reported for all single-element loop tests for which they were obtained up to the conclusion of experimental work. The results indicate that the use of new clay canisters increased the color rating of JP-5 fuel from around +19 to +30 (the +30 represents the lightest color, "water white"; −16 represents the darkest color). However, subsequent reblending of the fuel with corrosion inhibitors, testing, and retreating with clay led to rapid darkening in fuel color; usually, after four tests, color ratings had decreased to around +23, and remained at that level for 7 to 11 tests.

A closer look at the results of the Saybolt ratings indicates that no detectable color change occurred in the fuel immediately after blending with additive (comparing post-clay vs pre-test color ratings), and no detectable change occurred during any one test (comparing post-clay and pre-test color ratings vs post-test color ratings).

The greatest increases in fuel color occur soon after the initial clay treatment. These increases are abrupt and sizable and usually occur between the post-test measurement of one test and the post-clay treatment measurement of the following test. Thus, the increase in color appears to occur during the clay treatment. This suggests that color bodies removed from the raw fuel during the initial clay treatment are subsequently released; perhaps they are displaced as increasing amounts of corrosion inhibitors are adsorbed onto the clay.

In all cases, clay canisters were used only until they failed to restore fuel WSIM rating to 95 or higher. With this in mind, it is interesting to note, that, although these canisters remained effective on this basis for up to 11 tests,

they usually were unable to remove coloring agents in the fuel after only 4 tests. This leads one to the plausible conclusion that these coloring agents have little or no surface active properties, and that, in this respect, the Saybolt ratings were not useful in predicting fuel or fuel-additive blend performance in filter-separator tests.

During the course of filter-separator testing, not enough Saybolt color ratings were obtained on different corrosion inhibitor-fuel blends to determine if different systems promote fuel coloration more or less than others, although it does seem quite possible that this would be the case.

b. Effect on Element Performance Parameters

Another question of interest with regard to filter-separator testing is whether clay treating has any effect on the performance of filter-separator elements. Unfortunately, only two groups of tests were run in which all conditions were the same except for the use of untreated or clay-treated fuel. Results of these tests, run on JP-5 + 20 lb/Mbbl RP-2 + 0.15% FSII and using elements of Filters Inc. Lot 465, are given in Table 40. There is no significant difference between the mean parameter values for untreated JP-5 and clay-treated JP-5 except in the case of element

TABLE 40. EFFECT OF CLAY TREATMENT ON FILTER-SEPARATOR PERFORMANCE PARAMETERS OF JP-5 + 20 lb/Mbbl RP-2 + 0.15% FSII*

Parameter	Untreated JP-5 + 20 lb/ Mbbl RP + 0.15% FSII		Clay-treated JP-5 + 20 lb/ Mbbl RP + 0.15% FSII	
	Mean for 4 tests	SD	Mean for 9 tests	SD
Element wt gain, g	224	44	239	73
% dirt at 20 psi	110	27	116	37
% dirt at 40 psi	112	25	121	39
Avg AEL rating, mg/ℓ	27	30	21	16
Max AEL rating, mg/ℓ	39	41	45	41
Avg solids, mg/ℓ	0.18	0.03	0.17	0.05
Max solids, mg/ℓ	0.27	0.05	0.32	0.11
Avg Tot rating	7.5	15.0	1.9	2.8
Max Tot rating	25.2	49.2	11.0	18.7
Element ΔP at zero min, psi	1.62	0.12	1.93	0.11

*All tests performed according to procedure 13-A using only FI 465 elements and fuel from Batch 23.

differential pressure at start of test. The element differential pressure of 1.93 psi for the clay-treated fuel is greater than that for the untreated fuel (1.62 psi) by an amount which is statistically very highly significant. It is difficult to assign a cause for this difference in pressures. All the tests were run under identical conditions using fuel from a single batch (No. 23) and elements of a single lot (FI Lot 465). Time-related effects might be suspected here, since eight of the tests with clay-treated JP-5 were run first, followed by the four tests on untreated fuel, and lastly one additional test on clay-treated fuel. However, the differential pressure of the last test with clay-treated fuel is well in line with earlier results on clay treated fuel, which is evidence against the presence of time-related effects. The cause of the differences in mean element differential pressure is not apparent, and no suppositions can be formulated as to how clay treating can alter fuel properties to effect such a result.

Intuitively, clay-treating of fuel would be expected to result in improved test repeatability. However, comparison of standard deviations of performance parameters for clay-treated and untreated JP-5 (Table 40) does not support this supposition. Standard deviations for test parameters of clay-treated JP-5 are larger than those for untreated JP-5 in eight cases out of ten.

7. Injection Water Effects

During the program reported herein, only very limited data were obtained relating to the effects of injection water composition on filter-separator performance. A few tests on JP-5 + 16 lb/Mbbl Santolene C + 0.15% FSII were performed in which the injection water composition was varied. All of these tests were run according to Procedure 10 and involved Filters Inc elements from Lots 286 and 440. Injection water quality parameters are given in Section

TABLE 41. AVERAGE AEL RATING OF EFFLUENT FUEL FOR DIFFERENT TYPES OF INJECTION WATER

Test no.*	Injection water	Average free water, mg/ℓ			
		Min	Max	Mean	SD
64-68, 70-72, 77,91	Type B "synthetic"	0	8	1.9	2.1
74	pH5 (distilled + NaCl + HCl)	---	---	1.0	---
75	pH7 (distilled + NaCl + NaOH)	---	---	0	---
76	pH 10 (distilled + NaCl + NaOH)	---	---	0	---
78,79	65% Type B + 35% FSII	2	3	2.5	---
83	Type B + NaCl (932 mg/ℓ Cl^-)	---	---	0	---
96,99	Filtered WPAFB tap water	2	5	3.5	---
95	Distilled	---	---	3.0	---
92	pH 9.5 (Type B + NaOH)	---	---	4.0	---
93,94	Distilled (contaminated with residues from test 92)	2	2	2.0	---
97	pH 9.5 (Distilled + 164 mg/ℓ $NaHCO_3$ + NaOH)	---	---	1.0	---

*All tests performed on JP-5 + 16 lb/Mbbl Santolene C + 0.15% FSII according to procedure 10 with Filters Inc elements from Lots 286 and 440.

TABLE 42. AVERAGE SOLIDS CONTENT OF EFFLUENT FUEL FOR DIFFERENT TYPES OF INJECTION WATER

Test no.*	Injection water	Average solids content, mg/ℓ			
		Min	Max	Mean	SD
64-68, 70-72, 77,91	Type B "synthetic"	0.00	0.12	0.04	0.04
74	pH5 (distilled + NaCl + HCl)	---	---	0.07	---
75	pH7 (distilled + NaCl + NaOH)	---	---	0.01	---
76	pH10 (distilled + NaCl + NaOH)	---	---	0.03	---
78,79	65% Type B + 35% FSII	0.00	0.15	0.08	---
83	Type B + NaCl (932 mg/ℓ Cl^-)	---	---	0.03	---
96,99	Filtered WPAFB tap water	0.03	0.03	0.03	---
95	Distilled	---	---	0.14	---
92	pH 9.5 (type B + NaOH)	---	---	0.05	---
93,94	Distilled (contaminated with residues from test 92)	0.00	0.03	0.02	---
97	pH 9.5 (distilled + 164 mg/ℓ $NaHCO_3$ + NaOH)	---	---	0.01	---

*All tests performed on JP-5 + 16 lb/Mbbl Santolene C + 0.15% FSII according to procedure 10 with Filters Inc elements from Lots 286 and 440.

III of this report, and element performance parameters for tests with various injection waters are given in Tables 41 to 44. As can be seen, these results suggest that the variations of injection water composition that were used had no significant effect on any of the element performance parameters. It can be concluded that the water properties that were investigated either have no effect whatever on test severity, or that the effects are so insignificant that they are obscured by element-to-element variations. Although there was good evidence for believing that water properties could have significant effects on filter-separator performance on Santolene C blends, these test results show that this

TABLE 43. TIME TO REACH 20 PSI FOR DIFFERENT TYPES OF INJECTION WATER

Test no.*	Injection water	Time to reach 20 psi, min			
		Min	Max	Mean	SD
64-68, 70-72, 77,91	Type B "synthetic"	22	42	30.1	6.3
74	pH5 (distilled + NaCl + HCl)	--	--	35	--
75	pH7 (distilled + NaCl + NaOH)	--	--	32	--
76	pH10 (distilled + NaCl + NaOH)	--	--	30	--
78,79	65% Type B + 35% FSII	28	38	33	--
83	Type B + NaCl (932 mg/ℓ Cl^-)	--	--	27	--
96,99	Filtered WPAFB tap water	18	42	30	--
95	Distilled	--	--	31	--
92	pH 9.5 (Type B + NaOH)	--	--	32	--
93,94	Distilled (contaminated with residues from test 92)	26	31	28.5	--
97	pH 9.5 (distilled + 164 mg/ℓ $NaHCO_3$ + NaOH)	--	--	38	--

*All tests performed on JP-5 + 16 lb/Mbbl Santolene C + 0.15% FSII according to procedure 10 with Filters Inc elements from Lots 286 and 440

TABLE 44. ELEMENT WEIGHT GAIN FOR DIFFERENT TYPES OF INJECTION WATER

Test No.*	Injection water	Element weight gain, g			
		Min	Max	Mean	SD
64,66-68, 70-72, 77,91	Type B "synthetic"	147	267	197.9	37.2
74	pH5 (distilled + NaCl + HCl)	--	--	203	--
75	pH7 (distilled + NaCl + NaOH)	--	--	212	--
76	pH10 (distilled + NaCl + NaOH)	--	--	201	--
78,79	65% Type B + 35% FSII	179	220	199.5	--
83	Type B + NaCl (932 mg/ℓ Cl^-)	--	--	181	--
96,99	Filtered WPAFB tap water	141	248	194.5	--
95	Distilled	--	--	205	--
92	pH 9.5 (type B + NaOH)	--	--	192	--
93,94	Distilled (contaminated with residues from test 92)	173	222	197.5	
97	pH 9.5 (distilled + 164 mg/ℓ $NaHCO_3$ + NaOH)	--	--	248	

*All tests performed on JP-5 + 16 lb/Mbbl Santolene C + 0.15% FSII according to procedure 10 with Filters Inc elements from Lots 286 and 440

is not the case for the conditions investigated. This negative result has the practical implication that differences in mineral composition and pH of injection waters within the ranges tested are not likely to significantly affect filter-separator test results. This conclusion cannot be extended automatically to cover differences in types and amounts of particulate matter in water supplies, nor can it be extended to cover gross contamination of the water with surface-active materials.

Attempts to correlate element performance with such injection water quality parameters as surface tension, pH, and solids content proved fruitless because of a general lack of sufficient variation in any of these parameters.

8. Element Physical Parameters

a. Physical Variations

Three parameters (element weight, element differential pressure in the pressure-check trough, and element differential pressure at start of test) are related to physical variations in the elements. The level and degree of scatter of these parameters are of some interest and will be presented here. Of more importance is the extent of correlation between these element physical parameters and element performance parameters; this matter will also be taken up in this section.

Weight statistics for all element lots used in these tests are given in a preceding section of this report (Table 5). Regression and correlation analyses were performed in an attempt to establish the degree of correlation between element weight and any one of nine element performance parameters. Calculations were made on groups of tests having the same corrosion inhibitor, corrosion inhibitor concentration, FSII concentration, and element lot. The results of the calculations of correlation coefficient and its level of significance are summarized in Table 45.

TABLE 45. CORRELATION BETWEEN ELEMENT WEIGHT AND PERFORMANCE PARAMETERS

(All tests run according to Procedure 13-A unless otherwise noted)

*JP-5 Fuel Blend**

Corr inhib	Concn, lb/Mbbl	Element identification	No. of tests	Element weight vs									
				Avg AEL		Max AEL		Element wt gain		% Dirt load at 20 psi		% Dirt load at 40 psi	
				r	Signif %	r	Signif %	r	Signif %	r	Signif %	r	Signif %
Untreated													
Snt†	16	FI 286	15	0.47	5-10	0.06	>10	0.34	>10	0.33	>10	0.22	>10
Snt†	16	FI 440	9	0.34	>10	0.06	>10	0.58	>10	0.46	>10	0.45	>10
AFA‡	4	FI 465	5	0.10	>10	0.06	>10	0.61	>10	0.85	5-10	0.73	>10
RP	20	FI 465	4	0.75	>10	0.74	>10	0.95	2-5	0.98	1-2	0.98	1-2
Clay-treated													
Snt	16	FI 465	5	0.67	>10	0.70	>10	0.18	>10	0.47	>10	0.71	>10
Snt	16	Fr	4	0.04	>10	---	---	0.96	2-5	0.57	>10	0.73	>10
Snt	16	Bn	4	0.97	0.1-1	0.97	2-5	0.64	>10	-0.99	1-2	-0.99	0.1-1
Snt	16	Bw	4	0.60	>10	0.64	>10	0.48	>10	-0.39	>10	0.41	>10
AFA	16	FI 465	9	0.07	>10	0.04	>10	0.38	>10	0.34	>10	0.34	>10
AFA	16	Fr	4	0.66	>10	0.58	>10	0.11	>10	-0.68	>10	-0.71	>10
AFA	16	Bn	4	0.88	5	0.85	>10	0.99	0.1-1	-0.99	0.1-1	0.88	>10
AFA	16	Bw	4	0.67	>10	0.23	>10	0.23	>10	-0.59	>10	-0.71	>10
Lubr	20	FI 465	7	0.32	>10	0.16	>10	0.20	>10	0.21	>10	0.21	>10
Lubr	20	FI GS	4	0.47	>10	0.51	>10	0.02	>10	0.21	>10	0.21	>10
Lubr	20	Fr	4	0.77	>10	0.83	>10	0.02	>10	0.64	>10	0.64	>10
Lubr	20	Bn	4	0.24	>10	0.57	>10	0.27	>10	0.14	>10	0.14	>10
Lubr	20	Bw	4	0.22	>10	0.45	>10	0.96	2-5	0.65	>10	0.65	>10
RP	20	FI 465	9	0.22	>10	0.22	>10	0.42	>10	0.43	>10	0.01	>10
Snt**	16	FI 465	5	0.59	>10	0.50	>10	0.01	>10	0.50	>10	0.50	>10

TABLE 45. CORRELATION BETWEEN ELEMENT WEIGHT AND PERFORMANCE PARAMETERS (Cont'd)

(All tests run according to Procedure 13-A unless otherwise noted)

*JP-5 Fuel Blend**

Corr inhib	Concn, lb/Mbbl	Element identification	No. of tests	Element weight vs Avg solids		Max solids		Avg Totamitor		Max Totamitor	
				r	Signif %	r	Signif %	r	Signif %	r	Signif %
Untreated											
Snt†	16	FI 286	15	0.30	>10	0.23	>10	0.03	>10	0.18	>10
Snt†	16	FI 440	9	0.42	>10	0.50	>10	---	---	0.30	>10
AFA‡	4	FI 465	5	0.40	>10	-0.44	>10	-0.41	>10	-0.33	>10
RP	20	FI 465	4	0.19	>10	0.65	>10	0.75	>10	-0.75	>10
Clay-treated											
Snt	16	FI 465	5	-0.64	>10	-0.65	>10	-0.66	>10	-0.65	>10
Snt	16	Fr	4	0.52	>10	0.74	>10	0.32	>10	0.25	>10
Snt	16	Bn	4	0.94	5-10	0.93	5-10	---	---	-0.93	5-10
Snt	16	Bw	4	-0.65	>10	-0.80	>10	0.19	>10	0.22	>10
AFA	16	FI 465	9	-0.25	>10	-0.38	>10	-0.50	>10	0.34	>10
AFA	16	FR	4	0.63	>10	0.58	>10	---	---	0.47	>10
AFA	16	Bn	4	-0.03	>10	0.37	>10	---	---	-0.99	0.1-1
AFA	16	Bw	4	0.05	>10	0.38	>10	-0.88	>10	-0.88	>10
Lubr	20	FI 465	7	0.62	>10	0.47	>10	-0.17	>10	-0.24	>10
Lubr	20	FI GS	4	0.02	>10	-0.45	>10	0.40	>10	0.44	>10
Lubr	20	Fr	4	-0.73	>10	-0.92	5-10	0.53	>10	0.85	>10
Lubr	20	Bn	4	-0.08	>10	0.04	>10	-0.81	>10	0.57	>10
Lubr	20	Bw	4	0.04	>10	-0.40	>10	0.48	>10	---	---
RP	20	FI 465	[illegible]	0.44	>10	0.57	>10	0.43	>10	0.41	>10
Snt**	16	FI 465	5	0.92	2-5	-0.88	2-5	-0.97	0.1-1	0.20	>10

*Plus 0.15% FSII unless otherwise noted.
†Procedure 10.
‡Contained 0.10% FSII.
**Procedure 13-J.

Regression coefficients and equations were also calculated, but, in view of the generally low level of correlation, these are not reported here. If increased element weight is associated with increased media density, then it can be argued that there should be negative correlation between element weight and all the performance parameters in Table 45, except for average and maximum AEL ratings for which the sign of the correlation coefficient is not easily predicted. Examination of the correlation coefficients shows that there are slightly more positive than negative signs and that there is no great preponderance of either sign in the case of any parameter. On the basis of the results in Table 45, there is no evidence of correlation between element weight and any of the nine performance parameters.

b. Element Differential Pressure in Trough

Element differential pressure in trough statistics (mean and standard deviation) are given in Table 46 for tests on JP-5 fuel grouped according to element lot.

Correlations between element differential pressure in the pressure-check trough and the element performance parameters are summarized in Table 47; the general lack of correlation is obvious. The vast majority of

TABLE 46. DIFFERENTIAL PRESSURE IN TROUGH OF VARIOUS FILTER-SEPARATOR ELEMENTS

Fuel blend	Element identification	Element ΔP in trough, psi No. of tests	Mean	SD
JP-5, uninhibited	Filters Inc I4208, lot 465	42	0.768	0.435
JP-5, uninhibited	Filters Inc I4208, lot 516	5	1.720	0.259
JP-5, uninhibited	Filters Inc, Govt Std mfrd 10-68	4	2.325	0.236
JP-5, uninhibited	Fram CC-S11B, lot 14	12	0.975	0.277
JP-5, uninhibited	Bendix, part no. 04580004	12	1.017	0.518
JP-5, uninhibited	Bowser, part no. A 1389B	12	1.317	0.502

TABLE 47. CORRELATION BETWEEN ΔP IN TROUGH AND PERFORMANCE PARAMETERS

(All tests run according to Procedure 13-A unless otherwise noted)

*JP-5 Fuel Blend**

Contaminant	Concn, lb/Mgal	Element identification	No. of tests	ΔP in trough vs Avg AEL r	Avg AEL Signif %	Max AEL r	Max AEL Signif %	Element wt gain r	Element wt gain Signif %	% Dirt load at 20 psi r	% Dirt load at 20 psi Signif %	% Dirt load at 40 psi r	% Dirt load at 40 psi Signif %	Avg solids r	Avg solids Signif %	Max solids r	Max solids Signif %	Avg Totamiter r	Avg Totamiter Signif %	Max Totamiter r	Max Totamiter Signif %
Untreated																					
Sm†	16	FI 286	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sm*	16	FI 440	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
AFA‡	4	FI 465	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
RP	20	FI 465	4	0.47	>10	0.45	>10	0.70	>10	0.77	>10	0.75	>10	0.35	>10	-0.83	>10	0.47	>10	0.48	>10
Clay treated																					
Sm	16	FI 465	3	0.17	>10	0.22	>10	0.94	1-2	0.01	>10	0.92	2-5	0.16	>10	0.17	>10	0.21	>10	0.18	>10
Sm	16	Fr	4	0.65	>10	...	...	0.38	>10	0.42	>10	0.14	>10	0.17	>10	-0.36	>10	0.06	>10	0.15	>10
Sm	16	Bn	4	0.83	>10	0.74	>10	0.41	>10	0.56	>10	0.60	>10	0.49	>10	0.61	>10	...	...	0.68	>10
Sm	16	Bw	4	0.59	>10	0.61	>10	0.91	5-10	0.84	>10	0.87	>10	0.36	>10	0.42	>10	-0.53	>10	-0.70	>10
AFA	16	FI 465	9	0.07	>10	0.15	>10	0.67	2-5	0.59	5-10	0.60	5-10	0.29	>10	-0.35	>10	-0.40	>10	0.21	>10
AFA	16	Fr	4	0.17	>10	0.49	>10	0.19	>10	0.29	>10	0.34	>10	0.21	>10	0.48	>10	-0.42	>10	-0.99	1
AFA	16	Bn	4	0.33	>10	0.49	>10	[illegible]	>10	0.64	>10	0.66	>10	0.49	>10	0.11	>10	...	...	0.87	>10
AFA	16	Bw	4	0.16	>10	...	...	0.48	>10	0.86	>10	0.92	5-10	0.29	>10	0.24	>10	0.49	>10	0.49	>10
Lube	20	FI 465	7	0.72	5-10	0.75	5-10	0.16	>10	0.21	>10	0.21	>10	0.83	?	0.72	5-10	0.75	1-2	0.78	2-5
Lube	20	FI GS	4	0.60	1-2	0.99	0.1-1	[illegible]	>10	0.74	>10	0.74	>10	0.41	>10	0.34	>10	0.84	>10	-0.89	>10
Lube	20	Fr	4	0.29	>10	[illegible]	>10	0.80	>10	0.76	>10	0.76	>10	0.58	>10	0.52	>10	0.57	>10	0.13	>10
Lube	20	Bn	1	0.88	>10	0.85	>10	0.31	>10	0.54	>10	0.54	>10	0.09	>10	0.11	>10	0.95	5-10	0.85	>10
Lube	20	Bw	4	0.07	>10	0.43	>10	0.92	5-10	0.76	>10	0.76	>10	0.33	>10	0.32	>10	0.13	>10	...	...
RP	20	FI 455	9	0.21	>10	[illegible]	>10	[illegible]	>10	0.30	>10	0.30	>10	0.17	>10	0.39	>10	0.20	>10	0.33	>10
Sm**	16	FI 465	5	0.25	>10	0.43	>10	0.59	>10	0.84	5-10	0.58	>10	0.15	>10	0.12	>10	0.23	>10	0.78	>10

*Plus 0.1% LSD unless otherwise noted
†Procedure 10
‡Contained 0.10% LSD
**Procedure 13-J.

correlation coefficients are not statistically significant, even at the 10% level. Also, in the case of most performance parameters, the number of positive and negative correlation coefficients is about the same. In the case of two parameters, % dirt load at 20 psi and at 40 psi, almost all correlation coefficients are positive. This is paradoxical since for a given element design, tighter elements (higher differential pressures) would be expected to have lower dirt-holding capacities, hence the correlation coefficients would be expected to be negative.

c. Differential Pressure at Zero Minutes

Statistics (means and standard deviations) for element differential pressure at the start of test (zero min) are shown in Table 48 for tests run on a variety of JP-4 and JP-5 fuel blends using elements from several different lots. Since it is questionable whether or not the differential pressure is affected by the very small concentration of additives, the data in Table 48 are presented again in Table 49 with tests grouped only according to fuel type and element lot.

TABLE 48. ELEMENT DIFFERENTIAL PRESSURE AT ZERO MINUTES FOR VARIOUS COMBINATIONS OF FUEL BLEND AND ELEMENT

Fuel blend*			Element identification	Element ΔP at 0 minutes, psi		
Cor. inhib.	Concn, lb/Mbbl	FSII, vol %		No. of tests	Mean	SD
Sat†	4	0.15	FI 286	3	2.93	0.12
AFA‡	4	0.10	FI 465	3	1.93	0.19
none	—	0.00	FI 428	3	4.33	0.29
none	—	0.15	FI 286	3	5.03	0.61
Sat	16	0.00	FI 440	3	3.70	0.17
Sat	16	0.15	FI 286	3	4.27	0.21
Sat	16	0.15	FI 286	15	4.11	0.52
Sat**	16	0.15	FI 440	13	4.28	0.47
Sat**	16	0.15	FI 465	12	1.90	0.18
Sat**	16	0.15	FI 516	5	3.80	0.49
Sat**	16	0.15	Bn	4	4.40	0.24
Sat	16	0.15	Bw	4	4.72	0.15
AFA	4	0.10	FI 440A	7	4.60	0.32
AFA	16	0.15	FI 465	5	3.06	0.17
AFA**	16	0.15	FI 440	13	3.93	0.42
AFA**	16	0.15	FI 465	9	2.66	0.93
AFA**	16	0.15	Fr	4	4.25	0.13
AFA**	16	0.15	Bn	4	[illegible]	0.96
AFA**	16	0.15	Bw	4	[illegible]	0.41
AFA	16	0.15	FI 440A	8	4.00	0.73
Tol	20	0.15	FI 440	4	3.48	0.43
Lubr	20	0.15	FI 440	4	3.70	0.44
Lubr**	20	0.15	FI 465	7	2.30	0.57
Lubr**	20	0.15	FI GS	4	4.75	0.26
Lubr**	20	0.15	Fr	4	4.12	0.13
Lubr**	20	0.15	Bn	4	3.60	0.14
Lubr**	20	0.15	Bw	4	4.50	0.36
RP	20	0.15	FI 440	11	3.82	0.78
RP	20	0.15	FI 465	13	1.84	0.18
RP	20	0.15	FI 440A	3	4.90	0.26
EDS	14.5	0.15	FI 440	3	4.62	0.52
Uni	9	0.15	FI 440A	4	4.62	0.41
Uni	20	0.15	FI 440	3	4.07	0.86
Uni**	20	0.15	FI 465	3	2.10	0.34
Uni	20	0.15	FI 440A	4	4.68	0.27

*JP-5 fuel blend unless otherwise noted.
†JP-4 fuel blend.
‡JP-4 fuel blend, also contained 1.0 mg/l ASA.
**Clay-treated JP-5 fuel blend.

Results of correlation calculations shown in Table 50 suggest that for these tests there was no significant correlation between differential pressure at zero min and any of the element performance parameters.

d. Relationships Between Element Physical Parameters

It seems reasonable to expect correlation between pairs of the element physical parameters (element weight, element differential pressure in pressure-check trough, and element differential pressure at zero min). Regression and correlation analyses were performed on these parameters for groups of tests having the same fuel (JP-4 or JP-5) and the same element lot: results of these calculations are summarized in Table 51. Correlation was generally very poor, and, hence, regression coefficients and equations are not presented. In the cases of element weight vs differential pressure in trough and differential pressure in trough vs differential pressure at zero min,

TABLE 49. ELEMENT DIFFERENTIAL PRESSURE OF VARIOUS ELEMENT LOTS WHEN TESTED WITH JP-4 OR JP-5 FUEL

Element identification	Mean ΔP* at zero min, psi	
	JP-4	JP-5
FI 286	2.93	4.05
FI 428	—	4.33
FI 440	—	3.97
FI 440A	—	4.46
FI 465	1.93	2.28
FI 516	—	3.80
FI GS	—	4.75
Bn	—	3.97
Bw	—	4.38
Fr	—	4.18

*Flow rate 20 gpm.

TABLE 50. CORRELATION BETWEEN ΔP AT ZERO MIN AND PERFORMANCE PARAMETERS

(All tests run according to Procedure 13-A unless otherwise noted)

*JP-5 Fuel Blend**

Corr inhib	Concn, lb/Mbbl	Element identification	No. of tests	ΔP at zero min vs: Avg AEL		Max AEL		Element wt gain		% Dirt at 20 psi		% Dirt at 40 psi	
				r	Signif %	r	Signif %	r	Signif %	r	Signif %	r	Signif %
Untreated													
Snt†	16	FI 286	15	−0.29	>10	−0.34	>10	−0.69	0.1-1	−0.58	2-5	−0.55	2-5
Snt†	16	FI 440	9	−0.27	>10	−0.57	>10	−0.59	5-10	−0.56	>10	−0.60	5-10
AFA‡	4	FI 465	5	−0.41	>10	−0.76	>10	−0.32	>10	−0.01	>10	−0.63	>10
RP	20	FI 465	4	−0.13	>10	−0.14	>10	0.45	>10	0.63	>10	0.60	>10
Clay-treated													
Snt	16	FI 465	5	−0.59	>10	−0.55	>10	−0.04	>10	0.71	>10	−0.29	>10
Snt	16	Fr	4	−0.45	>10	---	---	−0.51	>10	0.41	>10	0.39	>10
Snt	16	Bn	4	0.74	>10	0.82	>10	−0.49	>10	−0.94	5-10	−0.92	5-10
Snt	16	Bw	4	0.27	>10	0.25	>10	−0.65	>10	−0.69	>10	−0.70	>10
AFA	16	FI 465	9	0.06	>10	0.27	>10	0.63	5-10	0.57	>10	0.60	5-10
AFA	16	Fr	4	−0.92	5-10	−0.89	>10	0.71	>10	0.98	1-2	0.98	2
AFA	16	Bn	4	−0.00	>>10	0.52	>10	0.07	>10	0.12	>10	0.45	>10
AFA	16	Bw	4	−0.87	>10	−0.12	>10	−0.18	>10	−0.34	>10	−0.44	>10
Lubr	20	FI 465	7	−0.08	>10	−0.47	>10	0.31	>10	0.28	>10	0.28	>10
Lubr	20	FI GS	4	−0.81	>10	−0.82	>10	0.81	>10	0.92	5-10	0.92	5-10
Lubr	20	Fr	4	−0.77	>10	−0.93	5-10	0.55	>10	−0.04	>10	−0.04	>10
Lubr	20	Br	4	0.82	>10	0.47	>10	−0.79	>10	−0.77	>10	−0.77	>10
Lubr	20	Bw	4	0.74	>10	0.73	>10	−0.01	>10	−0.55	>10	−0.55	>10
RP	20	FI 465	9	0.44	>10	0.37	>10	−0.03	>10	0.01	>10	−0.01	>10
Snt**	16	FI 465	5	−0.53	>10	−0.34	>10	−0.04	>10	0.72	>10	0.29	>10

Corr inhib	Concn. lb/Mbbl	Element identification	No. of tests	ΔP at zero min vs: Avg solids		Max solids		Avg Totamitor		Max Totamitor	
				r	Signif %	r	Signif %	r	Signif %	r	Signif %
Untreated											
Snt†	16	FI 286	15	−0.19	>10	−0.35	>10	−0.32	>10	−0.64	0.1-1
Snt†	16	FI 440	9	−0.13	>10	−0.12	>10	---	---	−0.10	>10
AFA‡	4	FI 465	5	−0.60	>10	−0.95	1-2	−0.70	>10	−0.68	>10
RP	20	FI 465	4	0.59	>10	0.47	>10	−0.13	>10	−0.13	>10
Clay-treated											
Snt	16	FI 465	5	−0.61	>10	0.60	>10	−0.57	>10	0.58	>10
Snt	16	Fr	4	0.67	>10	0.41	>10	0.87	>10	−0.84	>10
Snt	16	Bn	4	0.95	5	0.87	>10	...	...	−0.82	>10
Snt	16	Bw	4	0.41	>10	0.43	>10	0.62	>10	0.73	>10
AFA	16	FI 465	9	0.24	>10	−0.34	>10	−0.42	>10	−0.43	>10
AFA	16	Fr	4	0.20	>10	−0.42	>10	0.77	>10	0.14	>10
AFA	16	Bn	4	0.01	>10	0.91	5-10	...	...	...	...
AFA	16	Bw	4	0.52	>10	0.53	>10	0.92	5-10	0.95	2-5
Lubr	20	FI 465	7	0.75	1-2	−0.64	>10	−0.67	>10	−0.50	>10
Lubr	20	FI GS	4	0.26	>10	0.18	>10	−0.97	2-5	0.95	2-5
Lubr	20	Fr	4	0.50	>10	0.72	>10	0.29	>10	0.93	5-10
Lubr	20	Bn	4	0.13	>10	0.02	>10	0.28	>10	0.47	>10
Lubr	20	Bw	4	0.82	>10	0.78	>10	0.29	>10	...	...
RP	20	FI 465	9	0.34	>10	−0.45	>10	0.51	>10	0.52	>10
Snt**	16	FI 465	5	0.74	>10	0.83	5-10	0.41	>10	0.91	2-5

*Plus 0.15% FSII unless otherwise noted.
†Procedure 10
‡Contained 0.10% FSII.
**Procedure 13-J.

the number of positive and negative correlation coefficients is about the same and the coefficients are generally not statistically significant. In the case of differential pressure at zero min vs element weight, there are ten negative correlation coefficients out of a total of twelve. Although none of these coefficients is significant, even at the 10% level, the preponderance of negative coefficients suggests that there is negative correlation between differential pressure at zero min and element weight. However, negative correlation is the opposite of what would be expected. Logically, as element weight increases in a given element type, the amount of filtration media contained within the fixed element volume would increase, resulting in increased density and hence increased differential pressure (this is assuming there are no significant fluctuations in weights of end caps or cores).

TABLE 51. CORRELATION BETWEEN MEASURES OF ELEMENT PHYSICAL VARIATIONS

Fuel	Element	No. of tests	Element weight vs ΔP in trough		ΔP in trough vs ΔP at zero min		ΔP at zero min vs element weight	
			r	Signif %	r	Signif %	r	Signif %
Untreated JP-5								
JP-4	FI 286	16	---	---	---	---	−0.27	>10
JP-4	FI 465	8	---	---	---	---	0.32	>10
JP-5	FI 465	4	---	---	−0.19	>10	---	---
JP-5	FI 286	21	---	---	---	---	0.23	>10
JP-5	FI 428	6	---	---	---	---	−0.43	>10
JP-5	FI 440	56	---	---	---	---	−0.03	>10
JP-5	FI 440A	49	---	---	---	---	−0.09	>10
Clay-treated JP-5								
JP-5	FI 465	38	0.10	>10	0.19	>10	−0.12	>10
JP-5	FI 516	5	0.53	5-10	0.90	2-5	−0.31	>10
JP-5	FI GS	4	−0.56	>10	0.77	>10	−0.56	>10
JP-5	Fr	12	−0.24	>10	0.43	>10	−0.31	>10
JP-5	Bn	12	0.55	5-10	−0.38	>10	−0.06	>10
JP-5	Bw	12	−0.30	>10	−0.12	>10	−0.13	>10

In the foregoing attempts to determine correlation between element physical parameters, the indicated generally poor correlation may stem from the fact that, for a given set of conditions, the range of element physical parameters is too small to have much effect on the other parameters. In order to extend the range of element physical parameters, regression and correlation calculations were made on tests grouped according to procedure, fuel type, corrosion inhibitor, corrosion inhibitor concentration, other additives and FSII concentration and including all Filters Inc elements. This grouping of all Filters Inc lots may be justified since there were no apparent differences in construction of the various lots.

By lumping all Filters Inc elements together, relationships between element physical parameters, in tests run with JP-5 fuel, were as follows:

No. of data pairs	Regression equation	Correlation coefficient	
		Value	Signif, %
51	$P_t = 0.012W - 5.6$	0.46	<0.1
209	$P_o = 0.010W - 2.6$	0.64	<0.1
46	$P_o = 1.17P_t + 1.5$	0.72	<0.1

where

P_t = differential pressure in trough, psi

P_o = differential pressure at 0 min, psi

W = element weight, g

In all three cases, the correlation coefficients are positive and very highly significant. Thus, for this particular group of elements, total weight does bear a direct relation to flow resistance that is statistically significant despite various perturbing factors. Such factors might include variations in end cap and core weight, variations in technique of element fabrication, and variations in media composition or internal geometry.

9. Element Performance

In this section of the report, results of attempts to determine the difference in the performance of the various lots of elements will be given. Wherever enough comparable tests (four or more) were run on different lots of elements, the significance of the difference in means of the performance parameters for pairs of element lots was determined by use of *Student's t*. For convenience, the performance parameters are grouped under four classifications as follows: water removal, solids removal, solids retention capacity, and Totamitor readings.

Results of a series of tests involving three corrosion inhibitors and elements from four manufacturers will be used throughout this section for all comparisons between element lots. These tests were all run according to Procedure 13-A using clay-treated JP-5 fuel containing 0.15% FSII. All tests, except the 13 earliest,† were run as follows: all tests with a given additive were run in a group, using the same 600 gal of fuel (plus makeup after each test). Before each test, fuel was clay treated and then blended to the desired concentrations of corrosion inhibitor and FSII. Four elements of each manufacturer were tested with each fuel-additive blend. The order of testing elements was preselected randomly.

Means and standard deviations of the average AEL rating for these tests are given in Table 52 along with the level of significance of the differences in means for different manufacturer's elements. Statistically significant differences between means of average AEL free water are indicated for several pairs of element manufacturers in the tests involving either Santolene C or AFA-1. In the tests with Lubrizol, all elements had very similar performance. The subject of additive effects will be taken up in a later section of the report.

Similar results for the other element performance parameters for the same groups of tests are presented in Tables 53 to 60.

TABLE 52. COMPARISON OF AVERAGE AEL RATINGS FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn.* lb/Mbbl	Avg AEL rating		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	15	24	---	1-2.5	>50	>50
Fr	4	Snt	16	55	10	---	---	<0.1	1
Bn	4	Snt	16	16	6	---	---	---	25-50
Bw	4	Snt	16	22	14	---	---	---	---
FI 465	9	AFA	16	10	4	---	10-25	5-10	1-2.5
Fr	4	AFA	16	12	1	---	---	25-50	2.5-5
Bn	4	AFA	16	13	1	---	---	---	2.5-5
Bw	4	AFA	16	45	25	---	---	---	---
FI 465	7	Lubr	20	40	17	---	>50	>50	>50
Fr	4	Lubr	20	39	19	---	---	>50	>50
Bn	4	Lubr	20	43	27	---	---	---	>50
Bw	4	Lubr	20	45	20	---	---	---	---

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

†These early tests were performed with FI 465 elements, with fuel containing 16 lb/Mbbl Santolene C (5 tests), 16 lb/Mbbl AFA-1 (5 tests), and 20 lb/Mbbl Lubrizol 541 (3 tests). Test procedure was identical to that used in the later tests except for lack of rigid control over test sequence and fuel changes.

TABLE 53. COMPARISON OF MAXIMUM AEL RATINGS FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Max AEL rating		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	27	41	—	0.5-1	>50	>50
Fr	4	Snt	16	100	0	—	—	2.5-5	2.5
Bn	4	Snt	16	41	40	—	—	—	1-2.5
Bw	4	Snt	16	42	39	—	—	—	—
FI 465	9	AFA	16	19	5	—	>50	25-50	<0.1
Fr	4	AFA	16	12	1	—	—	25-50	0.1-0.5
Bn	4	AFA	16	22	6	—	—	—	0.1-0.5
Bw	4	AFA	16	88	25	—	—	—	—
FI 465	7	Lubr	20	88	31	—	>50	>50	>50
Fr	4	Lubr	20	80	40	—	—	>50	>50
Bn	4	Lubr	20	82	35	—	—	—	>50
Bw	4	Lubr	20	80	40	—	—	—	—

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 54. COMPARISON OF AVERAGE SOLIDS CONTENT FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Avg solids content, mg		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	0.59	1.20	—	25-50	25-50	25-50
Fr	4	Snt	16	0.08	0.04	—	—	>50	>50
Bn	4	Snt	16	0.09	0.05	—	—	—	>50
Bw	4	Snt	16	0.10	0.05	—	—	—	—
FI 465	9	AFA	16	0.10	0.04	—	5	>50	>50
Fr	4	AFA	16	0.14	0.03	—	—	—	25-50
Bn	4	AFA	16	0.09	0.01	—	—	—	25-50
Bw	4	AFA	16	0.12	0.06	—	—	—	—
FI 465	7	Lubr	20	0.68	0.34	—	>50	25-50	>50
Fr	4	Lubr	20	0.76	0.20	—	—	>50	>50
Bn	4	Lubr	20	1.04	0.79	—	—	—	25-50
Bw	4	Lubr	20	0.56	0.68	—	—	—	—

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 55. COMPARISON OF MAXIMUM SOLIDS CONTENTS FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Max solids content, mg		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	2.20	4.68	---	25-50	25-50	25-50
Fr	4	Snt	16	0.12	0.04	---	---	>50	25-50
Bn	4	Snt	16	0.16	0.12	---	---	---	>50
Bw	4	Snt	16	0.20	0.12	---	---	---	---
FI 465	9	AFA	16	0.20	0.12	---	25-50	>50	>50
Fr	4	AFA	16	0.26	0.08	---	---	10-25	10 > 25
Bn	4	AFA	16	0.18	0.04	---	---	---	>50
Bw	4	AFA	16	0.18	0.07	---	---	---	---
FI 465	7	Lubr	20	1.03	0.46	---	10-25	25-50	>50
Fr	4	Lubr	20	0.88	0.62	---	---	>50	>50
Bn	4	Lubr	20	1.40	0.27	---	---	---	>50
Bw	4	Lubr	20	2.28	0.25	---	---	---	---

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 56. COMPARISON OF ELEMENT WEIGHT GAIN FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Element wt gain		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	202	16	---	10-25	10-25	0.1-0.5
Fr	4	Snt	16	189	10	---	---	5-10	>50
Bn	4	Snt	16	239	42	---	---	---	10-25
Bw	4	Snt	16	196	26	---	---	---	---
FI 465	9	AFA	16	240	50	---	0.1-0.5	10-25	25-50
Fr	4	AFA	16	170	9	---	---	0.1-0.5	0.1-0.5
Bn	4	AFA	16	209	14	---	---	---	25-50
Bw	4	AFA	16	222	20	---	---	---	---
FI 465	7	Lubr	20	170	34	---	0.1-1.0	10-25	5-10
Fr	4	Lubr	20	118	13	---	---	5-10	5-10
Bn	4	Lubr	20	143	19	---	---	---	25-50
Bw	4	Lubr	20	178	49	---	---	---	---

*Blended with [illegible] 5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 57. COMPARISON OF % DIRT LOAD AT 20 PSI FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Dirt load at 20 psi, %		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	91	10	---	25-50	0.5-1	25-50
Fr	4	Snt	16	99	12	---	---	2.5-5	0.1-0.5
Bn	4	Snt	16	130	20	---	---	---	2.5-5
Bw	4	Snt	16	99	15	---	---	---	---
FI 465	9	AFA	16	115	25	---	0.5-1	10-25	50
Fr	4	AFA	16	86	5	---	---	1-2.5	0.5-0.1
Bn	4	AFA	16	101	66	---	---	---	10
Bw	4	AFA	16	111	81	---	---	---	---
FI 465	7	Lubr	20	88	16	---	1-2.5	2.5	25-50
Fr	4	Lubr	20	70	3	---	---	50	0.5-1
Bn	4	Lubr	20	66	11	---	---	---	1-2.5
Bw	4	Lubr	20	98	14	---	---	---	---

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 58. COMPARISON OF % DIRT LOAD AT 40 PSI FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Dirt load at 40 psi, %		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	108	24	---	25-50	2.5-5	50
Fr	4	Snt	16	102	14	---	---	2.5-5	50
Bn	4	Snt	16	134	21	---	---	---	5-10
Bw	4	Snt	16	106	16	---	---	---	---
FI 465	9	AFA	16	120	24	---	0.5-1	10-25	50
Fr	4	AFA	16	93	7	---	---	1-2.5	0.1-0.5
Bn	4	AFA	16	106	6	---	---	---	10
Bw	4	AFA	16	116	8	---	---	---	---
FI 465	7	Lubr	20	88	16	---	1-2.5	2.5	25-50
Fr	4	Lubr	20	70	3	---	---	50	0.5-1
Bn	4	Lubr	20	66	11	---	---	---	1-2.5
Bw	4	Lubr	20	98	14	---	---	---	---

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 59. COMPARISON OF AVERAGE TOTAMITOR RATINGS FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Avg Tot ratings		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	6	13	—	>50	25-50	>50
Fr	4	Snt	16	4	5	—	—	10-25	25-50
Bn	4	Snt	16	0	0	—	—	—	10-25
Bw	4	Snt	16	2	2	—	—	—	—
FI 465	9	AFA	16	0	0	—	2.5-5	25-50	5-10
Fr	4	AFA	16	1	0	—	—	2.5	10-25
Bn	4	AFA	16	0	0	—	—	—	5-10
Bw	4	AFA	16	4	3	—	—	—	—
FI 465	7	Lubr	20	4	4	—	0.1-0.5	0.5-1	1-2.5
Fr	4	Lubr	20	19	6	—	—	>50	>50
Bn	4	Lubr	20	21	8	—	—	—	>50
Bw	4	Lubr	20	18	9	—	—	—	—

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

TABLE 60. COMPARISON OF MAXIMUM TOTAMITOR RATINGS FOR ELEMENTS OF DIFFERENT MANUFACTURERS

Element	No. of elements	Corr inhib	Concn,* lb/Mbbl	Max Tot ratings		Probability of greater difference in means, %			
				Mean	SD	FI 465	Fr	Bn	Bw
FI 465	5	Snt	16	20	44	—	>50	25-50	>50
Fr	4	Snt	16	20	28	—	—	10-25	>50
Bn	4	Snt	16	1	0	—	—	—	1-2.5
Bw	4	Snt	16	12	7	—	—	—	—
FI 465	9	AFA	16	1	1	—	5-10	0.5-1	5-10
Fr	4	AFA	16	2	1	—	—	>50	10-25
Bn	4	AFA	16	2	1	—	—	—	10-25
Bw	4	AFA	16	17	16	—	—	—	—
FI 465	7	Lubr	20	26	28	—	<0.1	0.5-1	<0.1
Fr	4	Lubr	20	95	8	—	—	>50	25-50
Bn	4	Lubr	20	85	28	—	—	—	25-50
Bw	4	Lubr	20	99	0	—	—	—	—

*Blended with clay-treated JP-5 + 0.15% FSII and tested according to procedure 13-A.

In order to provide information about the overall performance of the different elements, Table 61 was prepared. This table gives the rank (1, 2, 3, 4 in order of decreasing performance) for each element for the various performance parameters.

For these particular groups of tests' an overall rank of the elements in order of decreasing effectiveness is as follows:

(1) FI 465

(2) Bendix

(3) Bowser

(4) Fram

It should be emphasized that in the case of several parameters, the differences in means for the various elements are not statistically significant. Also, the overall rank is an unweighted average without any real statistical significance. Hence, the overall ranking can be regarded only as indicative of general performance in this particular test program.

Four tests, similar to those run in the test series dealt with above, were run using JP-5 + 20 lb/Mbbl Lubr + 0.15% FSII and Filters Inc elements from government supply. Results of these four tests are given in Table 62 along with results of seven similar tests in which Filters Inc Lot 465 elements were used. Comparison of results from these two groups of tests shows that the elements from government stock exhibited slightly better mean performance parameters in every case. In most cases, however, the differences are not statistically significant; in only one case, that of element weight gain, is the difference in means significant at better than the 5% level. The choice of Lubrizol 541 as the fuel corrosion inhibitor placed all of these tests well into the "failure" zone, so the results are not necessarily indicative of relative element performance under less severe conditions.

TABLE 61. RANK OF ELEMENTS FOR VARIOUS PERFORMANCE PARAMETERS

Parameter	Corr inhib	Element identification			
		FI 465	Fr	Bn	Bw
Avg AEL, mg/ℓ	Snt	1	4	2	3
	AFA	1	2	3	4
	Lubr	2	1	3	4
Max AEL, mg/ℓ	Snt	1	4	2	3
	AFA	2	1	3	4
	Lubr	3	1	2	1
Avg solids, mg/ℓ	Snt	4	1	2	3
	AFA	2	4	1	3
	Lubr	2	3	4	1
Max solids, mg/ℓ	Snt	4	1	2	3
	AFA	2	3	1	1
	Lubr	2	1	3	4
Element wt gain, g	Snt	2	4	1	3
	AFA	1	4	3	2
	Lubr	2	4	3	1
Dirt load at 20 psi, %	Snt	3	2	1	2
	AFA	1	4	3	2
	Lubr	2	3	4	1
Dirt load at 40 psi, %	Snt	2	4	1	3
	AFA	1	4	3	2
	Lubr	2	3	4	1
Avg Totamitor	Snt	4	3	1	2
	AFA	1	2	1	3
	Lubr	1	3	4	2
Max Totamitor	Snt	3	3	1	2
	AFA	1	2	2	3
	Lubr	1	3	2	4
Average rank		2.0	2.7	2.3	2.5
Average overall rank		1	4	2	3

*Concentrations: 16 lb/Mbbl Snt, 16 lb/Mbbl AFA, 20 lb/Mbbl Lubr. Clay-treated JP-5 fuel blends all contained 0.15% FSII.

Also among the elements that were tested in this program were some identified by the manufacturers as special elements capable of removing red iron oxide, Pfizer R-9998*, from inhibited fuel. Three Bowser and three Bendix elements of this type were tested in the Al/SS loop according to a modified 8901-B inhibited fuel test procedure in which the solid contaminant was Pfizer R-9998 red iron oxide instead of AC dust.

*This is slightly coarser than the Fisher I-116 red iron oxide normally used in filter-separator testing.

TABLE 62. COMPARISON OF PERFORMANCE OF FILTERS INC LOT 465 ELEMENTS WITH FILTERS INC ELEMENTS FROM GOVERNMENT SUPPLY

Performance parameter*	FI 465†		FI GS‡		Signif level, %
	Mean	SD	Mean	SD	
Avg AEL, mg/ℓ	40	17	28	13	10-25
Max AEL, mg/ℓ	88	31	52	33	10-25
Avg solids, mg/ℓ	0.68	0.34	0.40	0.28	10-25
Max solids, mg/ℓ	1.03	0.46	0.88	0.62	>50
Element wt gain, g	170	34	208	19	2.5-5
Dirt load at 20 psi, %	88	16	105	10	5-10
Dirt load at 40 psi, %	88	16	105	10	5-10
Avg Totamitor	4	4	1	2	10-25
Max Totamitor	26	28	13	18	25-50

*All tests run according to Procedure 13-A using clay-treated JP-5 + 20 lb/Mbbl Lubr + 0.15% FSII.
†Seven tests.
‡Four tests.

The modified 8901-B inhibited-fuel tests consisted of flowing fuel through the test filter-separator at 20 gpm, injecting water at 0.2 gpm throughout the test, and injecting solid contaminant (in this case red iron oxide) at a rate of 2.86 g/min, starting at 60 min into the test and continuing until the end of the test (either at 40-psi differential pressure or at 130 min of testing). Two tests were run on each manufacturer's elements using JP-5 fuel containing 0.15% FSII and 10 lb/Mbbl AFA-1 corrosion inhibitor. One test was run on each manufacturer's element using JP-5 fuel without corrosion inhibitor. In all tests involving corrosion inhibitor, the elements exhibited very unsatisfactory performance. Effluent fuel was highly contaminated: maximum Totamitor readings ranged from 53 to 100, average solids contents ranged from 1.23 to 10.03 mg/ℓ, maximum solids contents ranged from 2.46 to 17.57 mg/ℓ, and maximum free water contents ranged from 18 to 20+ mg/ℓ. In these inhibited-fuel tests, performance of both manufacturer's elements was unsatisfactory, but the Bowser elements were appreciably better in filtration efficiency, giving average effluent solids contents of 2.62 and 1.23 mg/ℓ in comparison with 10.03 and 9.60 mg/ℓ for the Bendix elements. It may be noted that even the "better" efficiency of the Bowser elements was poor in terms of normal performance standards. This difference in filtration efficiency may be related to the differences in plugging behavior of the two manufacturers' elements. Bowser elements plugged rapidly, the pressure drop exceeding 40 psi at 86 and 87 min, in comparison with pressure drops of only 8.4 and 8.5 psi in 130-min tests with the Bendix elements. With regard to effluent Totamitor readings and free water contents, there was no appreciable difference between Bowser and Bendix elements.

10. Additive Effects

a. Fuel Quality Parameters

The effects of various additives, FSII, and corrosion inhibitors on WSIM and IFT values were studied using pre-test measurements on loop-test fuel. Only a few tests were performed on fresh JP-4. The great majority of tests were performed on JP-5 which contained 0.15% FSII. Generally, corrosion inhibitors were tested only at minimum effective and maximum allowable concentrations* in fresh JP-5, and only at maximum allowable concentrations in clay-treated JP-5.

1. *Effect of FSII*

The relative effect of 0.15% FSII in fresh JP-4, fresh JP-5, and clay-treated JP-5 is shown below:

Fuel	No. of tests	Mean WSIM	Mean IFT
JP-4	2	100	40.5
JP-4 + 0.15% FSII	3	93.7	40.0
JP-5	1	92.0	40.0
JP-5 + 0.15% FSII	6	87.0	43.8
JP-5 (CT†)	2	97.5	47.5
JP-5 (CT†) + 0.15% FSII	2	94.0	45.0

*As set forth in QPL-25017-7. NaSul EDS, a formerly qualified corrosion inhibitor, was also tested.
†CT = clay-treated.

Because of the limited number of tests, no firm conclusions can be drawn. Qualitatively, it appears that FSII tends to decrease WSIM for all fuels tested. One would expect an additive which is mutually soluble in both water and fuel (such as FSII) to affect adversely the interfacial properties, at least to a small extent.

For IFT, the effect of FSII is less apparent, and probably cannot be determined without performing more tests. In the tests reported above, IFT increased for one type of fuel, decreased for one type of fuel, and remained essentially the same for another type of fuel.

(2) Effect of Corrosion Inhibitors

Single-element tests involving JP-4 fuel plus additives were very limited in number. The only comparative WSIM and IFT data on corrosion inhibitor effects at different concentrations are those for Santolene C in JP-4 containing 0.15% FSII.

Sant concn. lb/Mbbl	No. of tests	Mean WSIM	Mean IFT
0	3	93.7	41.0
4	2	93.0	35.7
16	2	76.0	30.0

Again, due to the limited number of data, only qualitative conclusions can be drawn. These data do indicate that both the WSIM and IFT vary inversely with concentration of Santolene C; however, unlike the FSII, this corrosion inhibitor seems to have a greater effect on IFT than on WSIM. The relative decreases caused by 16 lb/Mbbl of Santolene C (expressed as percentages of the corresponding zero-concentration value) are 18.8% for the WSIM and 26.8% for the IFT.

More extensive data are available on blends with fresh JP-5 + 0.15% FSII. Relative effects of different corrosion inhibitors on WSIM and IFT are shown in Table 63. For every additive tested, both WSIM and IFT decreased as concentration increased; however, by looking at the plots of IFT and WSIM vs concentration shown in Figure 6, some interesting conclusions about the rate of decrease can be drawn. First considering WSIM, the AFA-1, Santolene C and RP-2, were similar in that small amounts gave significant decreases in WSIM, and further addition of inhibitor gave very little effect. This is not the case with any of the other additives tested. Tolad 244, Lubrizol 541, NaSul EDS, and Unicor M all tended to have a much more constant rate of decrease in WSIM as concentration increased.

With respect to IFT, all corrosion inhibitors gave decreases, but the shapes of the curves were not sufficiently different to differentiate among corrosion inhibitors.

TABLE 63. EFFECT OF CORROSION INHIBITORS ON FUEL QUALITY PARAMETERS

Fuel: Fresh JP-5 + 0.15% FSII

Corr inhib	Concn, lb/Mbbl	No. of tests	WSIM		IFT, dyn/cm	
			Mean	SD	Mean	SD
none		6	87.0	6.0	43.3	1.5
Sant	4	4	71.2	7.9	38.6	2.6
	16	35	71.1	9.7	34.9	2.7
AFA	4	4	62.2	4.5	33.2	1.0
	16	21	60.9	10.9	23.3	1.2
Tol	5.5	2	60.0	—	35.2	—
	20	4	30.2	1.8	25.2	1.9
Lubr	5	1	62.0	—	33.0	—
	20	3	42.3	3.2	26.3	0.6
RP	7	1	44.0	—	30.5	—
	20	18	42.3	5.9	27.1	2.7
EDS	14.5	4	11.0	9.8	13.5	1.7
Uni	9	5	59.8	12.1	32.0	4.8
	20	7	31.3	6.3	23.7	5.6

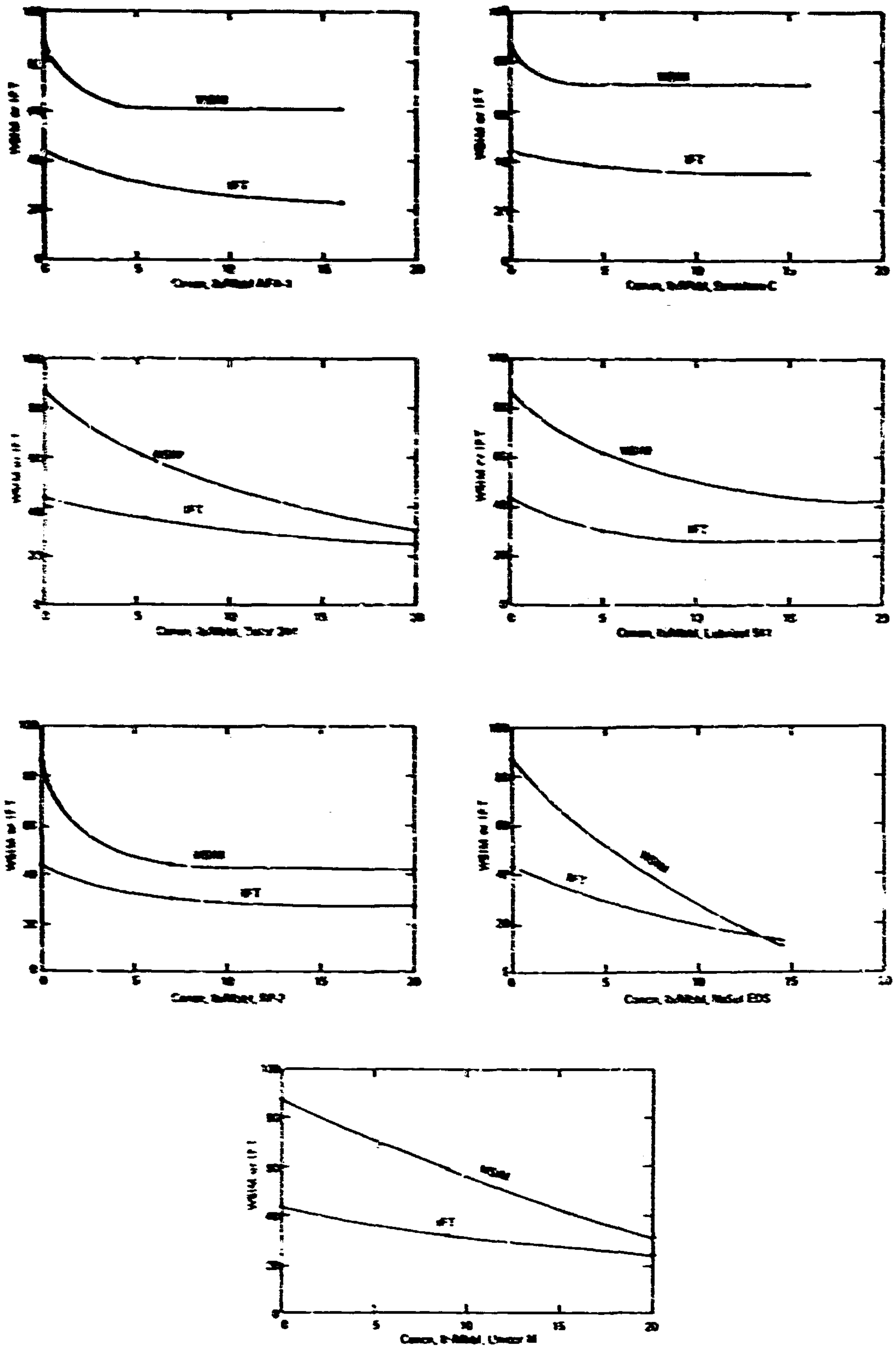

FIGURE 6. EFFECT OF CORROSION INHIBITOR CONCENTRATION
ON QUALITY PARAMETERS OF FRESH
JP-5 + 0.15% FSII

In principle, it should be possible to relate concentration plots to the critical micelle concentration of surface-active substances. Insufficient data are available to judge whether such relationships exist for WSIM or IFT.

WSIM and IFT decreases for each inhibitor at the maximum concentration tested are expressed as a percentage of the zero-concentration value and are listed below in order of increasing effect:

WSIM		IFT	
Snt	18.3%	Snt	20.3%
AFA	30.0%	RP	38.1%
Lubr	51.4%	Lubr	40.0%
RP	51.4%	Tol	42.5%
Uni	64.0%	Uni	45.9%
Tol	65.5%	AFA	46.8%

This display shows that WSIM and IFT do not decrease at equivalent rates for every corrosion inhibitor and that certain inhibitors affect one parameter to a far greater degree than the other.

b. Element Performance Parameters

The measures of element performance that are considered in the following paragraphs are (1) element weight gain, (2) percent dirt load at 20 and 40 psi, (3) average and maximum AEL ratings, (4) average and maximum solids contents, and (5) average and maximum Totamitor ratings.

(1) Effect of FSII

The effect of FSII (in both JP-4 and JP-5) on element performance parameters is presented in Table 64. The only group of tests from which any comparable data could be extracted were those which had all test conditions the same except FSII content of the respective fuels. The only groups of tests which met these conditions were those which were performed according to Procedure 10 with Filters Inc elements from Lot 286. As can be seen from Table 64 for both JP-4 and JP-5, the only parameters which were adversely affected by the presence of FSII in the fuel were those concerned with the solids retention capacity of the element—element weight gain, percent dirt load at 20 psi, and percent dirt load at 40 psi. All other performance parameters are measures of effluent fuel quality, these were either unaffected or improved by the presence of FSII. However, improvement of the parameters may be fortuitous due to the extreme variability of these parameters and the limited number of tests.

TABLE 64. EFFECT OF FSII IN FRESH FUEL ON DIFFERENT FILTER-SEPARATOR PERFORMANCE PARAMETERS*

Mean values of performance parameters for different concn of FSII

Parameters	Fresh JP-4		Fresh JP-5	
	0% FSII (2 tests)	0.15% FSII (3 tests)	0% FSII (1 test)	0.15% FSII (3 tests)
Element wt gain, g	642	540	418	317
% dirt at 20 psi	346	308	186	151
% dirt at 40 psi	390	347	209	152
Avg AEL rating	2	2	2	0
Max AEL rating	7	4	3	0
Avg solids, mg/ℓ	0.10	0.02	0.08	0.02
Max solids, mg/ℓ	0.26	0.04	0.21	0.02
Avg Tot rating	0	0	0	3
Max Tot rating	0	1	0	0

*All tests were performed according to Procedure 10 using FI 286 elements.

(2) Effect of Corrosion Inhibitors

In JP-4 fuel, effects on performance parameters could be determined for only one inhibitor, Santolene C. The results of tests run on three different concentrations of this inhibitor in JP-4 + 0.15% FSII are

TABLE 65. EFFECT OF SANTCLENE C CONCENTRATION IN JP-4 ON DIFFERENT FILTER-SEPARATOR PERFORMANCE PARAMETERS*

Mean values of performance parameters for different concn of Snt

Parameter	0 lb/Mbbl (3 tests)	4 lb/Mbbl (3 tests)	16 lb/Mbbl (2 tests)
Element wt gain, g	540	394	285
% dirt at 20 psi	308	188	113
% dirt at 40 psi	347	225	138
Avg AEL rating	2	2	6
Max AEL rating	4	5	6
Avg solids, mg/ℓ	0.02	0.05	0.04
Max solids, mg/ℓ	0.04	0.08	0.06
Avg Tot rating	0	0	0
Max Tot rating	1	0	0

*All tests were performed according to Procedure 10, using FI 286 elements and JP-4 + 0.15% FSII.

shown in Table 65. In general, increasing the concentration of Santolene C affected adversely every measure of element performance except Totamitor ratings, and, as was the case for FSII, this phenomenon was particularly evident in element parameters relating to solids retention capacity.

When considering the relative effect of corrosion inhibitors on JP-5, the conditions under which every qualified inhibitor† was tested were as follows: clay-treated fuel +0.15% FSII, Procedure 13-A, and Filters Inc elements from Lot 465. Table 66 shows the mean values of every parameter for each corrosion inhibitor as well as the relative rank of each inhibitor with respect to any given parameter.

The tabulated results strongly suggest that there is considerable difference in the effects of the various inhibitors on filter-separator performance. The inhibitors are arranged in order, from left to right, of overall increasing deleterious effect on filter-separator performance. Because of the small number of tests on three of the corrosion inhibitors and the fact that all of the data were obtained from tests with one manufacturer's filter-separator elements, it is not possible to conclude that the relative ranking will be generally true.

TABLE 66. RELATIVE EFFECT OF CORROSION INHIBITORS ON DIFFERENT FILTER-SEPARATOR PERFORMANCE PARAMETERS*

Parameters	AFA 16 lb/Mbbl (9 tests)		RP 20 lb/Mbbl (9 tests)		Tol 20 lb/Mbbl (2 tests)		Snt 16 lb/Mbbl (5 tests)		Uni 20 lb/Mbbl (3 tests)		Lubr 20 lb/Mbbl (7 tests)	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Element wt gain, g	240	1	239	2	126	6	202	3	176	4	170	5
% Dirt at 20 psi	115	2	116	1	66	6	91	3	86	5	88	4
% Dirt at 40 psi	120	2	121	1	66	6	108	3	87	5	88	4
Avg AEL rating	10	1	21	4	13	2	15	3	26	5	40	6
Max AEL rating	19	1	45	5	25	2	27	3	41	4	88	6
Avg solids, mg/ℓ	0.10	1	0.17	4	0.16	3	0.59	5	0.15	2	0.68	6
Max solids, mg/ℓ	0.20	1	0.32	4	0.23	3	2.20	6	0.22	2	1.03	5
Avg Tot rating	0	1	2	2	2	2	6	4	6	4	4	3
Max Tot rating	1	1	11	3	6	2	20	4	29	6	26	5

*All tests were performed according to Procedure 13-A using FI 465 elements and clay-treated JP-5 + 0.15% FSII. Each corrosion inhibitor was tested at maximum allowable concentration stated in QPL-25017-7.

†According to QPL-25017-7.

11. Relationships Between Element Performance Parameters

The relationships which exist between different element performance parameters were investigated by means of correlation and regression analysis, and results of these investigations are reported in this section. Among the element performance parameters that are compared, are element dirt load at 20 and 40 psi, as well as the following measures of effluent fuel quality: average and maximum AEL rating; average and maximum solids content; average and maximum Totamitor reading.

Considering those tests which had the same combinations of fuel, additives, element, and procedure, ten correlation calculations were performed as follows:

(1) average AEL rating vs average solids content

(2) average AEL rating vs average Totamitor reading

(3) average solids content vs % dirt load at 20 psi

(4) average solids content vs % dirt load at 40 psi

(5) average solids content vs average Totamitor reading

(6) average Totamitor reading vs % dirt load at 20 psi

(7) average Totamitor reading vs % dirt load at 40 psi

(8) maximum AEL rating vs maximum solids content

(9) maximum solids content vs maximum Totamitor reading

(10) maximum Totamitor reading vs maximum AEL rating.

With these grouping conditions applied, only calculations number 2, 6, 7, and 10 resulted in any noticeable trend of correlation. Table 67, which shows results of correlation calculations for average AEL rating and average Totamitor reading, indicates that positive correlation exists. Most of the correlation coefficients are high and statistically significant; they are also all positive. These results indicate that, for every combination of conditions on which these calculations were performed, the Totamitor reading varied directly with the AEL ratings. A look at the regression equations, also shown in Table 67, indicates that all of the regression coefficients lie in the range of 0.1 to 0.5.

Results of efforts to correlate average solids content with average Totamitor reading for the same combinations were not as productive of consistent results. Out of eleven correlation coefficients obtained, five are positive and six negative. It cannot, however, be concluded from these results that the average Totamitor reading is not influenced by the average solids content. In fact, the contrary is true, as will be shown in the following paragraphs. It can be concluded that the effect of solids on Totamitor reading is subject to a great deal more scatter than that of free water. The effect of solids is far less precise than the effect of water on Totamitor reading.

Correlation coefficients for maximum Totamitor reading vs maximum AEL rating were generally positive, but generally not statistically significant. Results (shown in Table 68) indicate that for most combinations tried (13 out of 17) the maximum Totamitor reading varied directly with the maximum AEL rating. Because of the great variability of results, the regression equations are not presented. Maximum solids content vs maximum Totamitor reading calculations proved even less consistent with nine correlation coefficients being positive and nine being negative. These facts merely support the conclusion that free water has a more precise and reproducible effect on Totamitor readings than does solids content.

TABLE 67. CORRELATION BETWEEN AVERAGE AEL AND AVERAGE TOTAMITOR RATINGS

*JP-5 Fuel Blend**

Corr inhib	Concn, lb/Mbbl	FSII, %	Element identification	No. of tests	Regression equation	Correlation coefficient	Coefficient signif level, %
Untreated							
Snt†	16	0.15	Fl 286	15	T = 0.1A – 0.1	0.89	<0.1
Snt†	16	0.15	Fl 440	9	–	–	–
AFA	4	0.10	Fl 465	5	T = 0.3A + 0.5	0.85	2-5
RP	20	0.15	Fl 465	4	–	–	–
Clay-treated							
Snt	16	0.15	Fl 465	5	T = 0.5A – 1.7	0.99	<0.1
Snt	16	0.15	Fr	4	T = 0.4A – 16.6	0.80	10
Snt	16	0.15	Bn	4	–	–	–
Snt	16	0.15	Bw	4	T = 0.1A – 1.0	0.89	2-5
AFA	16	0.15	Fl 465	9	–	–	–
AFA	16	0.15	Fr	4	–	–	–
AFA	16	0.15	Bn	4	–	–	–
AFA	16	0.15	Bw	4	T = 0.1A – 2.3	0.94	1-2
Lubr	20	0.15	Fl 465	7	T = 0.1A – 2.0	0.67	5-10
Lubr	20	0.15	Fl GS	4	T = 0.1A – 2.2	0.89	2-5
Lubr	20	0.15	Fr	4	T = 0.3A + 8.2	0.84	5-10
Lubr	20	0.15	Bn	4	T = 0.2A + 11.2	0.69	>10
Lubr	20	0.15	Bw	4	T = 0.4A + 0.4	0.86	5-10
RP	20	0.15	Fl 465	9	T = 0.2A – 1.6	0.96	0.1-1
Snt‡	16	0.15	Fl 465	5	–	–	–

*Tested according to procedure 13-A unless otherwise noted.
†Procedure 10.
‡Procedure 13-J.

TABLE 68. CORRELATION BETWEEN MAXIMUM TOTAMITOR READINGS AND MAXIMUM AEL RATINGS

*JP-5 Fuel Blend**

Corr inhib	Concn, lb/Mbbl	FSII, %	Element identification	No. of tests	Correlation coefficient	Coefficient signif level, %
Untreated						
Snt†	16	0.15	Fl 286	15	0.69	0.1-1
Snt†	16	0.15	Fl 440	9	–0.07	>10
AFA	4	0.10	Fl 465	5	0.66	>10
RP	20	0.15	Fl 465	4	0.99	0.1-1
Clay-treated						
Snt	16	0.15	Fl 465	5	0.99	<0.1
Snt	16	0.15	Fr	4	–	–
Snt	16	0.15	Bn	4	–0.99	0.1-1
Snt	16	0.15	Bw	4	0.84	5-10
AFA	16	0.15	Fl 465	9	–0.02	>10
AFA	16	0.15	Fr	4	0.41	>10
AFA	16	0.15	Bn	4	–0.85	5-10
AFA	16	0.15	Bw	4	0.41	>10
Lubr	20	0.15	Fl 465	7	0.40	>10
Lubr	20	0.15	Fl GS	4	0.94	1-2
Lubr	20	0.15	Fr	4	0.01	>10
Lubr	20	0.15	Bn	4	0.01	>10
Lubr	20	0.15	Bw	4	–	–
RP	20	0.15	Fl 465	9	0.77	1
Snt‡	16	0.15	Fl 465	5	0.12	>10

*Tested according to procedure 13-A unless otherwise noted.
†Procedure 10.
‡Procedure 13-J.

Average Totamitor readings, when compared with percent dirt load at 20 and 40 psi, were found to decrease as percent dirt load increased for 12 out of 16 combinations. This effect can possibly be interpreted as follows. As the element encounters more solid contaminant, its efficiency in removing solids may be improved due to an effective reduction in pore size by the buildup of a cake of solids within the media. This effect is, however, self-limiting, and rupture of the element is bound to occur if the amount of solids becomes sufficient to severely restrict fuel flow through the element. This effect does not necessarily have to impair the water-removing efficiency of the element. It is plausible that the effect of dirt loading on element performance as represented by Totamitor readings may not be the same for different manufacturer's elements. However, no detectable difference in the behavior of different elements with respect to this correlation could be observed. The results of these correlation calculations are presented in Table 69.

Results of similar attempts to correlate average solids content with percent dirt at 20 and 40 psi are shown below.

Parameters compared	Correlation coefficients
Avg solids vs % dirt (20 psi)	10 pos, 9 neg
Ave solids vs % dirt (40 psi)	11 pos, 8 neg

TABLE 69. CORRELATION BETWEEN AVERAGE TOTAMITOR READING AND % DIRT LOAD AT 20 AND 40 PSI

*JP-5 Fuel Blend**

Corr inhib	Concn, lb/Mbbl	FSII, %	Element identification	No. of tests	Average Totamitor reading vs % dirt load at 20 psi: Corr coef	Signif level, %	vs % dirt load at 40 psi: Corr coef	Signif level, %
Untreated								
Snt†	16	0.15	FI 286	15	0.07	>10	0.05	>10
Snt†	16	0.15	FI 440	9	—	—	—	—
AFA	4	0.10	FI 465	5	−0.13	>10	−0.19	>10
RP	20	0.15	FI 465	4	−0.74	>10	−0.78	>10
Clay-treated								
Snt	16	0.15	FI 465	5	−0.41	>10	−0.54	>10
Snt	16	0.15	Fr	4	−0.01	>10	−0.10	>10
Snt	16	0.15	Bn	4	—	—	—	—
Snt	16	0.15	Bw	4	−0.91	2-5	−0.88	5
AFA	16	0.15	FI 465	9	−0.06	>10	−0.10	>10
AFA	16	0.15	Fr	4	0.68	>10	−0.71	>10
AFA	16	0.15	Bn	4	—	—	—	—
AFA	16	0.15	Bw	4	0.14	>10	0.29	>10
Lubr	20	0.15	FI 465	7	−0.11	>10	−0.11	>10
Lubr	20	0.15	FI GS	4	−0.98	0.1-1	−0.98	0.1-1
Lubr	20	0.15	Fr	4	0.04	>10	0.04	>10
Lubr	20	0.15	Bn	4	−0.54	>10	−0.54	>10
Lubr	20	0.15	Bw	4	−0.51	>10	−0.51	>10
RP	20	0.15	FI 465	9	0.33	>10	0.30	>10
Snt‡	16	0.15	FI 465	5	−0.29	>10	−0.35	>10

*Tested according to procedure 13-A unless otherwise noted.
†Procedure 10.
‡Procedure 13-J

For all but two combinations, the coefficients were not statistically significant; in the two cases for which the coefficients were significant, they were of different sign.

A knowledge of whether coalescence and filtration failures generally occur simultaneously was thought to be useful in rating element performance.

Efforts to correlate AEL ratings with solids contents, either for the average or the maximum, gave no conclusive results for the combinations tried. Below is a summary of results obtained:

Parameters compared	Correlation coefficients
Avg AEL vs avg solids	13 pos, 6 neg
Max AEL vs max solids	13 pos, 5 neg

In these comparisons, most correlations were not statistically significant. Of those that were statistically significant, some were positive and some negative coefficients. Therefore, it is impossible to determine conclusively whether coalescence and filtration failures tend to occur simultaneously on the basis of the test conditions used.

All of the results discussed in the preceding paragraphs were obtained from all groups of four or more tests which had the same combinations of fuel, additives, element, and procedure; therefore, in most cases, the results are derived from a small number of tests. Because of the inherent variability of the measurements being considered, true relationships between different parameters can be obscured when only a few sample-tests are investigated. In an effort to increase the number of tests for a given comparison, certain conditions for grouping were relaxed; this resulted in the following findings.

By considering those groups of tests which had only the same combinations of additives and elements (without restricting test procedure), the general trend of correlation between average AEL rating and average solids content is not substantially improved. Table 70, which presents the results of correlation calculations on these groups, shows that nine of thirty-one coefficients are negative. Considering only those which are statistically significant (5% probability of a greater correlation coefficient occurring by chance), there are six positive coefficients and only one negative. This suggests that in most cases there is a trend toward simultaneous coalescence and filtration failure; however, no pattern of better or worse correlation for different element lots or different corrosion inhibitors could be detected.

Considering groups of tests which had the same combinations of solids, fuel, and additives (without restricting the type of elements) likewise did not improve the correlation. Eight of

TABLE 70. CORRELATION BETWEEN AVERAGE AEL RATING AND AVERAGE SOLIDS CONTENT

Corr inhib	Other additive	Element	No. of tests	Correlation coefficient	Coefficient signif level, %
none	none	FI 286	9	0.37	>10
none	PtL	FI 440A	5	0.77	5-10
none	PtCR	FI 440A	8	0.93	<0.1
none	NA-1	FI 465	4	–0.26	>10
Snt	none	FI 286	22	0.01	>10
Snt	none	FI 440	13	0.88	<0.1
Snt	none	FI 465	12	0.97	<0.1
Snt	none	FI 516	5	0.70	>10
Snt	none	Fr	4	–0.25	>10
Snt	none	Bn	4	0.88	5-10
Snt	none	Bw	4	0.17	>10
Snt	none	FI 440A	10	0.73	1
AFA	none	FI 440	13	–0.46	10
AFA	none	FI 465	18	0.23	>10
AFA	none	Fr	4	0.35	>10
AFA	none	Bn	4	0.00	>10
AFA	none	Bw	4	–0.42	>10
AFA	none	FI 440A	10	0.20	>10
Tol	none	FI 440	6	0.27	>10
Lubr	none	FI 440	4	–0.85	5-10
Lubr	none	FI 465	7	0.04	>10
Lubr	none	FI GS	4	0.34	>10
Lubr	none	Fr	4	–0.93	2
Lubr	none	Bn	4	–0.06	>10
Lubr	none	Bw	4	0.24	>10
RP	none	FI 440	11	0.74	0.1-1
RP	none	FI 465	13	0.11	>10
RP	none	FI 440A	5	0.46	>10
EDS	none	FI 440	4	0.28	>10
Uni	none	FI 440	4	–0.44	>10
Uni	none	FI 440A	8	–0.03	>10

twenty correlation coefficients were negative; only three of the positive and one of the negative coefficients were statistically significant. The results are shown in Table 71.

TABLE 71. CORRELATION BETWEEN AVERAGE AEL RATING AND AVERAGE SOLIDS CONTENT (DISREGARDING ELEMENT LOT)

Fuel	Corr inhib	Other additive	Type of solids	No. of tests	Correlation coefficient	Coefficient signif level, %
JP-4	none	none	coarse AC dust	5	0.07	>10
JP-4	none	ASA	coarse AC dust	5	-0.09	>10
JP-4	Snt	none	coarse AC dust	5	0.42	>10
JP-5	none	none	coarse AC dust	4	0.73	>10
JP-5	none	none	RIO (I-116)	3	0.87	>10
JP-5	none	PtL	coarse AC dust	5	0.77	5-10
JP-5	none	PtCR	coarse AC dust	8	0.94	<0.1
JP-5	none	NA-1	coarse AC dust	4	-0.26	>10
JP-5	Snt	none	coarse AC dust	48	0.41	0.1-1
JP-5	Snt	none	fine AC dust	15	0.22	>10
JP-5	AFA	none	coarse AC dust	35	-0.06	>10
JP-5	AFA	none	fine AC dust	12	0.14	>10
JP-5	AFA	none	RIO (R-9998)	5	-0.88	2
JP-5	Tol	none	coarse AC dust	7	-0.56	>10
JP-5	Lubr	none	coarse AC dust	26	-0.24	>10
JP-5	RP	none	coarse AC dust	18	0.28	>10
JP-5	RP	none	fine AC dust	10	0.54	5-10
JP-5	Uni	none	coarse AC dust	6	0.94	<0.1
JP-5	Uni	none	fine AC dust	5	-0.19	>10
JP-5	Uni	none	50% coarse, 50% fine AC dust	7	-0.25	>10

By considering all effluent fuel samples (A, B, and C) for all the tests reported herein, without regard to test conditions, the following correlation coefficients for Totamitor reading vs AEL rating and Totamitor reading vs solids content are obtained.

Totamitor reading vs AEL rating (750 samples)		Totamitor reading vs solids content (759 samples)	
r	Level of signif	r	Level of signif
0.69	<<0.1%	0.27	<0.1%
Regression equation Tot = 0.6 AEL + 0.5; Tot = 2.7 solids + 5.2			

The plots of the regression equations are shown in Figure 7. As can be seen, the slope of the line associated with solids content is much steeper than that concerned with AEL rating. This suggests that solids content has a much more pronounced effect on Totamitor readings than does free water.* However, free water has a much more precise and consistent effect on Totamitor readings, as was noted earlier.

*This tentative conclusion obviously applies only to the specific contaminants and test conditions in this program. Here, solid material in the effluent will tend to be the finer fraction of the solid contaminant, and water in the effluent will tend to be partially coalesced, medium-size droplets that are entrained through the separator. When these conditions apply, i.e., so long as the element has not suffered gross failure, the solids will have a greater effect on light scattering than will equal concentration of free water. Where failure is more severe, these relative effects are likely to be reversed.

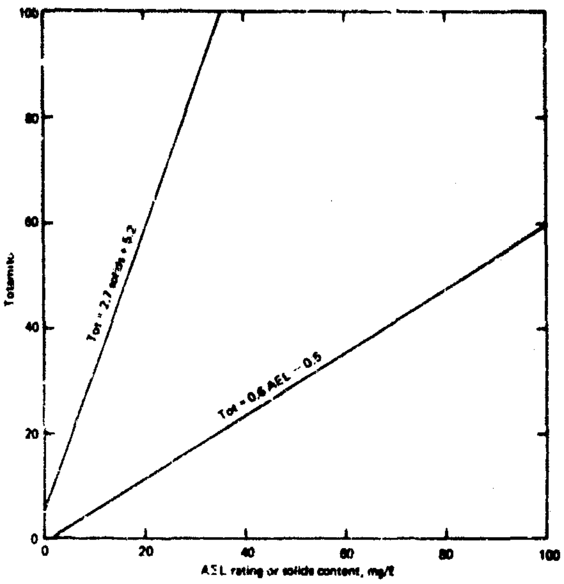

FIGURE 7. CORRELATIONS BETWEEN TOTAMITOR RATINGS AND SOLIDS CONTENTS AND AEL RATINGS

TABLE 72. CORRELATION BETWEEN AVERAGE SOLIDS + AVERAGE AEL AND AVERAGE TOTAMITOR READING

Fuel	Corr inhib	Concn, lb/Mbbl	No. of tests	Correlation coefficient	
				Value	Signif level, %
JP-4	none	--	10	0.89	0.1-1
JP-4	AFA	4	6	−0.09	>10
JP-5	none	0	37	0.78	<0.1
JP-5	Snt	4	4	0.99	<0.1
JP-5	Snt	16	68	0.58	<0.1
JP-5	AFA	4	5	0.76	1
JP-5	AFA	10	4	0.47	>10
JP-5	AFA	16	44	0.17	>10
JP-5	Tol	20	6	0.58	>10
JP-5	Lubr	20	28	0.40	2-5
JP-5	RP	20	27	0.81	<0.1
JP-5	EDS	14.5	4	0.00	>10
JP-5	Uni	9	5	0.99	<0.1
JP-5	Uni	20	10	0.92	<0.1

When average Totamitor is compared to the sum of average solids content and average AEL rating, good positive correlation is obtained. Table 72 shows the resulting correlation coefficients when only those tests which have the same fuel corrosion inhibitor blends are compared. Of fourteen coefficients, only one is negative and one is zero. With all grouping restrictions removed except type of fuel, the following correlation coefficients are obtained:

Fuel	Correlation between Totamitor and AEL + solids content		
	Coefficient	Level of signif	Regression equation
JP-4 (24 tests)	0.63	<0.1%	T = 0.1 (A + S) − 0.2
JP-5 (251 tests)	0.53	<<0.1%	T = 0.3 (A + S) + 0.7

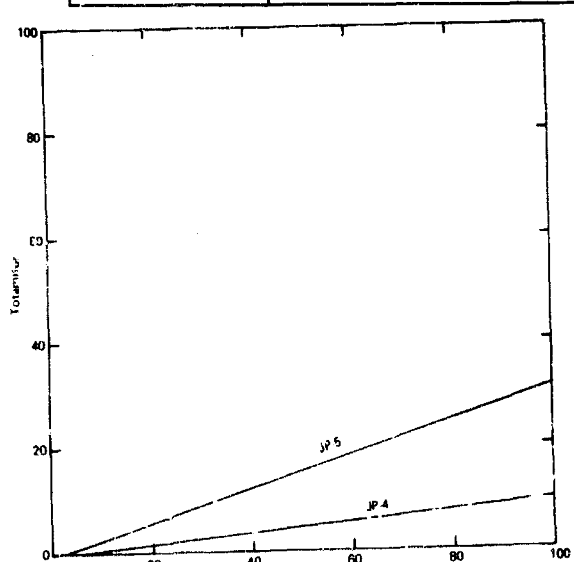

FIGURE 8. AVERAGE TOTAMITOR READING VS AVERAGE AEL RATING + AVERAGE SOLIDS CONTENT FOR JP-4 AND JP-5

Plots of the regression equations are shown in Figure 8. These data indicate that Totamitor readings are more sensitive to changes in contamination level of JP-5 than of JP-4. This relationship is applicable only to the tests in this particular program and may be fortuitous.

12. Comparison of Test Procedures

Twenty-nine different loop test procedures were used in obtaining the data presented in this report. Many of these procedures were used only once or twice, so that no comparisons of relative severity can be obtained. Among the procedures used in a greater number of tests, direct comparisons of procedure severity are invalidated in many cases because of differences in fuel, additive, or element lot. Direct comparisons of procedure severity are valid in only three cases, in which Procedure 13-J is compared with Procedures 10, 13-N, or 13-A. It will be recalled that Procedure 10, using coarse AC dust, is fairly similar to the MIL-F-8901A inhibited-fuel procedure, and the

others follow a "dirt-first" schedule with coarse AC dust (13-A), fine AC dust (13-J), or a 50-50 mixed dust (13-N).

These comparisons are listed in Tables 73 through 75. Inspection of these comparative data reveals that the parameters related to element plugging, i.e., solids retention capacity (percent dirt load and element weight gain) behaved differently than the parameters related to effluent cleanliness (solids and water contents and Totamitor readings). Statistical significance of the differences in test procedure severity cannot be assessed for two of the three comparisons because of insufficient number of tests by one procedure or the other. Qualitatively, the procedure severities line up as shown in the following tabulation, where statistical significance of differences is shown as NS (not significant), VHS (very highly significant), or U (unknown, insufficient data):

Procedure	13-J more severe or less severe	
	Effluent cleanliness	Solids capacity
13-J vs 13-N	More (U)	Same (U)
13-J vs 13-A	Less (NS)	More (VHS)
13-J vs 10	More (U)	Same (U)

One would expect Procedure 13-J to be the most severe, since this procedure includes the use of the finest of the test contaminants. In terms of solids capacity, the data are in agreement with this expectation, since the sole significant difference indicates Procedure 13-J to be more severe than 13-A. In the parameters related to effluent cleanliness, statistical significance cannot be ascribed to the differences observed, but qualitative differences in the direction of greater severity for 13-J are noted in two out of three cases. These differences in effluent cleanliness are across-the-board; i.e., in a given comparison of two procedures, the solids and water contents and the Totamitor readings all pointed in the same direction.

The comparison of Procedure 13-J with 13-A gave quite a different picture of relative severity than did the comparisons of 13-J with 13-N or 10. The major difference was in the plugging behavior (solids retention capacity), as illustrated by the following list of dirt loads at 40 psi:

	13-J vs 13-N	13-J vs 13-A	13-J vs 10
% dirt load at 40 psi:			
13-J	112	63	114
13-N	113		
13-A		108	
10			110
JP-5 clay-treated:	No	Yes	No
Corrosion inhibitor	AFA	Snt	Snt
Element lot no.	440A	465	440

In the 13-J tests used for comparison with 13-A, the plugging was much more severe than in any of the other tests by any procedure, including 13-J. Reasons for this difference are not readily apparent. In these particular 13-J tests, the fuel was clay-treated, and the elements came from a different lot than those used in the other tests. Thus, the rapid plugging observed with fine AC dust in those 13-J tests is evidently not a general phenomenon, but is specific for certain combinations of test materials.

Similar comparisons in Table 76 indicate little difference in average AEL ratings for tests run with different solid contaminants, except that significantly higher AEL ratings were obtained with coarse AC dust than with either fine red iron oxide (I-116) or ground iron ore. Coarse AC dust and ground iron ore were used in comparable procedures (Procedure 13 type) and the comparisons may be valid. The fine red iron oxide (I-116) was

TABLE 73. COMPARISON OF PROCEDURES 13-J AND 10

Fuel: JP-5
Corrosion inhibitor: 16 lb/Mbbl Snt
FSII: 0.15%
Element lot: FI 440

Performance parameter	Proc 13-J			Proc 10		
	No. of tests	Mean	SD	No. of tests	Mean	SD
Dirt load at 20 psi, %	3	114	15.3	9	91	21.4
Dirt load at 40 psi, %	3	114	15.3	9	110	22.2
Avg AEL rating, mg/ℓ	3	10	8.5	9	2	1.4
Max AEL rating, mg/ℓ	3	21	9.0	9	4	2.3
Avg solids content, mg/ℓ	3	0.20	0.11	9	0.05	0.05
Max solids content, mg/ℓ	3	0.36	0.19	9	0.11	0.10
Avg Totamitor	3	6	9.8	9	0	0
Max Totamitor	3	24	56.6	9	1	1.8

TABLE 74. COMPARISON OF PROCEDURES 13-J AND 13-N

Fuel: JP-5
Corrosion inhibitor: 16 lb/Mbbl AFA
FSII: 0.15%
Element lot: FI 440A

Performance parameter	Proc 13-J			Proc 13-N		
	No. of tests	Mean	SD	No. of tests	Mean	SD
Dirt load at 20 psi, %	3	105	5.7	3	107	27.2
Dirt load at 40 psi, %	3	112	13.1	3	113	20.7
Avg AEL rating, mg/ℓ	3	27	21.9	3	13	4.2
Max AEL rating, mg/ℓ	3	68	55.4	3	24	11.0
Avg solids content, mg/ℓ	3	3.20	1.86	3	1.90	1.84
Max solids content, mg/ℓ	3	7.76	5.36	3	5.68	6.40
Avg Totamitor	3	10	4.5	3	6	7.9
Max Totamitor	3	69	51.4	3	29	33.8

TABLE 75. COMPARISON OF MEAN ELEMENT PERFORMANCE PARAMETERS FOR PROCEDURES 13-J AND 13-A TESTS

Performance parameter	Parameter values for indicated procedures*				Level of significance of difference in mean, %
	13-J†		13-A†		
	Mean	SD	Mean	SD	
Element wt gain, g	129	8	202	16	<0.1
% Dirt at 20 psi	62	3.4	91	10.4	<0.1
% Dirt at 40 psi	63	4.7	108	24.5	<0.1
Avg AEL, mg/ℓ	7	2.4	15	24.3	>50
Max AEL, mg/ℓ	14	4.5	27	41.0	25-50
Avg solids, mg/ℓ	0.19	0.10	0.59	1.20	25-50
Max solids, mg/ℓ	0.57	0.45	2.20	4.67	25-50
Avg Totamitor	0.2	0.4	6	12.9	25-50
Max Totamitor	2	1.0	20	44.2	25-50

*All tests conducted on clay-treated JP-5 fuel with 16 lb/Mbbl Snt + 0.15% FSII using F.I. lot of 465 elements.
†Five tests.

TABLE 76. MEAN AVERAGE AEL RATINGS FOR DIFFERENT TYPES OF SOLIDS

Solids*	No. of tests	Average AEL rating		% chance greater difference in means				
		Mean	SD	FAC	I-116	R-9998	GIO	50-50
CAC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25-50	[illegible]	[illegible]
FAC	[illegible]	[illegible]	[illegible]	—	[illegible]	>50	25-50	>50
I-116	4	[illegible]	[illegible]		—	25-50	>50	>50
R-9998	[illegible]	[illegible]	[illegible]			—	>50	>50
GIO	[illegible]	[illegible]	[illegible]				—	>50
50-50	[illegible]	[illegible]	[illegible]					—

*Solids identification:
CAC Coarse AC dust
FAC Fine AC dust
I-116 Red iron oxide, Fisher
R-9998 Red iron oxide, Pfizer
GIO [illegible]
50-50 50% coarse AC dust, 50% fine AC dust

TABLE 77. MEAN AVERAGE SOLIDS CONTENTS FOR DIFFERENT TYPES OF SOLIDS

Solids*	No. of tests	Average solids content		% chance greater difference in means				
		Mean	SD	FAC	I-116	R-9998	GIO	50-50
CAC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	>50	[illegible]
FAC	[illegible]	[illegible]	[illegible]	—	>50	5-10	[illegible]	[illegible]
I-116	4	[illegible]	[illegible]		—	25-50	25-50	[illegible]
R-9998	[illegible]	[illegible]	[illegible]			—	[illegible]	[illegible]
GIO	3	[illegible]	[illegible]				—	[illegible]
50-50	[illegible]	[illegible]	[illegible]					—

*Solids identification.
CAC Coarse AC dust
FAC Fine AC dust
I-116 Red iron oxide, Fisher
R-9998 Red iron oxide, Pfizer
GIO [illegible]
50-50 50% coarse AC dust, 50% fine AC dust

used in only four tests listed in the table and three of these were run according to Procedure 12, which is essentially the MIL-F-8901A red iron oxide emulsion ("slurry") test. Hence, comparisons between results from tests using coarse AC dust and fine red iron oxide are probably not valid.

Table 77 indicates that mean average solids content was significantly higher with fine than with coarse AC dust. This seems reasonable and may be valid since there are adequate numbers of tests in each case and the two dusts were used in comparable test procedures. Other indications provided by Table 77 are probably not as valid, and in some cases are contradictory to differences in contaminant particle size. For example, the results indicate that higher solids contents were obtained in tests with coarse AC dust than in tests with a mixture of 50% fine and 50% coarse AC dust.

13. Special Tests

a. General

During the course of filter-separator testing, a limited number of atypical tests were performed. Some were one-of-a-kind tests performed during procedure development. Others were tests performed during special evaluations. And, still others were tests performed on defective elements. Due to the uniqueness of these tests, results obtained were deleted in computer analysis. They, therefore, do not influence, in any way, results obtained from statistical analyses of normal tests.

TABLE 78. LOOP TEST PROCEDURES USED ONCE

Test no.	Procedure
[illegible]	*
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible] with fuel test at 40-gpm fuel flow rate
[illegible]	[illegible] with fuel test at 20-gpm fuel flow rate
[illegible]	[illegible] water removal test
[illegible]	[illegible] and water test

[illegible]

b. Unrepeated Tests

A number of tests performed either during procedure development or during special evaluations were run once by a given procedure and were not repeated. These tests are listed in Table 78.

c. Special Evaluations

During the program reported herein, three Bowser filter-separator elements* which had been in service at Andrews AFB were examined. At Andrews AFB, considerable difficulty had been experienced with premature plugging of elements. At the time of receiving the three elements, it was the opinion of Propulsion Laboratory personnel that the plugging might be attributed to excess plug valve grease getting into the fuel. Consequently, it was considered desirable to run special loop tests in which plug valve grease was injected. In the course of studying this problem, several types of tests were performed, as described in the paragraphs that follow.

Visual examination of the used elements from Andrews AFB revealed several small particles of soft greaselike, brownish material. Some of these particles were collected and furnished to the Propulsion Laboratory for further examination.

The elements on hand were tested in the pressure-check trough at a flow rate of 20 gpm of JP-5, with the following results:

No. 1: 16.3 psi
No. 2: 20.0 psi
No. 3: 15.6 psi

Element no. 1 was cleaned by immersion in isopropanol for 24 hr, after which a recheck on pressure drop at rated fuel flow indicated 3 psi. Evidently, the isopropanol removed most of the material that had plugged the element in service. The isopropanol used in cleaning the element was found to contain 1 to 2% glycerol.

Element no. 2 was tested as-received, in loop test no. 299, using clay-treated JP-5 containing 0.15 vol % FSII but no corrosion inhibitor. This fuel gave WSIM values of 92 to 95. The loop test was run as a straight coalescence test without any solids injection. The test schedule included 30 min at 20 gpm with 0.01% water injection, then three 10- to 15-min periods with 1% water injection while the fuel flow rate was set successively at 20, 15, and 10 gpm, and finally a recheck on pressure drop at 20 gpm without any water injection. The coalescing performance was very poor. All AEL samples taken during water injection indicated free water contents in excess of 20 mg/L, most of them far above 20. Effluent Totamitor readings ranged from 10 to 100. The differential pressure started at 23.8 psi but had increased to 25.1 at the end of the 15-min pre-test period, before any water had been injected. The differential pressure continued to rise during the test, dropping back when flow rate was decreased. The final check at 20 gpm, without water injection, indicated a differential pressure of 29.1 psi.

A new Bowser element (similar to those used at Andrews AFB) was checked for the effect of plug valve grease in a series of four tests, nos. 300A through 300D, using clay-treated JP-5 (0.15% FSII) throughout the series without intermediate clay treatment. Fuel WSIM values ranged from 91 to 98. The first test (300A) included the injection of some 46 g of MIL-G-6032 plug valve grease into the influent fuel stream by means of a grease gun.

*Bowser A-13892 elements, military-standard type.

About 15 g of grease was injected over a 30-min period, after which coalescence was checked by successive water injections at 0.01 and 1% of fuel flow. The second grease injection (about 31 g) was performed over a 30-min period while 1% water was being injected. The grease injection did not degrade element performance to any serious extent. The differential pressure increased to 7.8 psi from an initial value of 4.4 psi. Totamitor readings were zero throughout, and the highest content of free water in the effluent was 7 to 8 mg/ℓ according to the AEL ratings. Effluent solids contents were higher than normal, ranging from 0.70 to 0.99 mg/ℓ. After the test series was completed, the element was found to contain small, uniformly distributed particles of grease inside the perforated metal core. Subsequent tests in this series were run on the same fuel, reblending to 0.15% FSII for test 300B but omitting the FSII makeup in the last two tests. Tests 300B, 300C, and 300D included periods of fuel flow without any water injection, as well as water injection at 0.01 and 1%, but did not include any further injection of solid material. In each test, the differential pressure remained below 8 psi for a 20-gpm flow rate; in test 300D, the differential pressure rose to 10.8 psi during a period when the fuel flow rate was 30 gpm. Coalescence was only fair, with AEL ratings generally near 10 mg/ℓ but occasionally as high as 18 to 19 mg/ℓ. Solids contents were low, all below 0.4 mg/ℓ, and effluent Totamitor readings were zero throughout.

The series of tests just described, run on a new element, failed to reveal any severe plugging or serious degradation of performance when 46 g of this particular plug valve grease was injected into the influent fuel.

Tests 301 and 302 were run with injection of Walworth No. 1 plug valve sealant, which is a relatively hard stick-form grease that is in use at Andrews AFB. In test 301, the element was the isopropanol-cleaned element recovered from an Andrews filter-separator. The injection of 57 g of grease produced only slight plugging, the differential pressure increasing from 6.2 psi to 8.5 psi. Coalescence was very poor; several of the AEL ratings were far in excess of 20/ℓ. In test 302, using a new element, 75 g of grease was injected, again with little plugging effect (initial differential pressure 4.3 psi, final 6.1 psi). Coalescence was excellent, all AEL ratings being less than 5 mg/ℓ. Effluent solids contents were low in both of these tests. Examination of the elements after test revealed that essentially all the injected grease had collected in a mass at the top of the perforated core of the element; hence, the lack of plugging effect is not surprising.

Tests 303A and 303B were run successively on a new Bowser element, using the same JP-5 fuel used in previous tests, without any clay treatment or makeup of FSII. These tests were run to determine whether injection of glycerol along with coarse AC dust would plug the element. Starting with an initial pressure differential of 4 psi, the injection of 4000 ml of glycerol along with 29 g of coarse AC dust produced a differential of 19 psi. This dropped to 9 to 10 psi in subsequent periods of fuel flow and water injection (0.01 and 1%) and then to 5 psi after shutdown and restart. Next, after another shutdown, coarse AC dust was injected up to a differential pressure of 20 psi; this required 314 g, or a total of 343 g counting that injected previously. Subsequent injection of 670 ml of glycerol over a 5-min period increased the differential to 25 psi, which remained substantially constant during a 30-min water injection period (1%) that followed. Coalescence was satisfactory during the water injection periods. Solids contents of the effluent samples ranged up to 0.73 mg/ℓ during the initial injection of glycerol and solids, but remained below 0.2 mg/ℓ in subsequent operations. During the two periods of glycerol injection (at 0.09 and 0.18% of fuel flow), it was observed that most of the glycerol was coalesced and drawn off the bottom of the test housing. Examination of the pressure-differential curves for these tests suggests that the glycerol causes a buildup in flow resistance but subsequently "works through" the element so that the pressure differential drops off again. The combination of glycerol and coarse AC dust does not give particularly severe plugging. With a total of 343 g of dust, which is about 170% of the nominal dirt-holding capacity of the element, the pressure differential was only some 25 psi. This may be contrasted with the plugging behavior of coarse AC dust in tests on JP-5 fuel containing corrosion inhibitors, where the element seldom accepted much more than 200 g (100% rated capacity) without exceeding the plugging limit of 40 psi.

Thus, it was not possible for this limited series of tests to establish a probable cause for the plugging problems encountered at Andrews AFB. Since a wash in isopropanol did "unplug" one of the Andrews elements, it is evident that organic material contributed to the plugging, and the presence of glycerol was established. Attempts to duplicate such plugging in short-term tests with glycerol or plug valve grease were unsuccessful. In the field, organic materials derived from the glycerol component of FSII, from the plug valve grease, or from interactions of these materials with solid inorganic contaminants and fuel gums may be the cause of premature plugging failures.

d. Tests on Defective Elements

Several tests were run on elements which had manufacturing defects or which had been damaged during installation. Also, one test was run on an element which had been cut away for visual observations. These tests are listed below:

Test no.	Element identification	Remarks
57	FI Lot 286	Excessive initial pressure drop (45 psi)
not numbered	FI Lot 286	Excessive initial pressure drop (10 psi); this element was replaced and the test restarted.
98	FI Lot 440	Element crushed during installation.
107	FI Lot 440	Element sectioned for observation.
113	FI Lot 440	Element had broken end cap.
225	FI Lot 465	Element's filtration and coalescence performance was satisfactory, post-test examination revealed split.
229	FI Lot 465	Element's filtration performance was satisfactory; coalescence was poor; post-test examination revealed large bulge on element.

In test 57, after only 4 min of fuel flow at 20 gpm with no solids or water injection, the element ΔP had increased to 45 psi and the test was terminated. Subsequent weighing of the element indicated no significant increase in weight, and no explanation for the unusually high initial differential pressure could be formulated.

Shortly after test 57, another excessive initial differential pressure (10 psi) was observed. In this case, the results were not assigned a test number; the element was replaced and a numbered test was run.

The element used in test 98 was inadvertently crushed during its installation in the test section. This resulted in excessive free water passage into the effluent, and the test was terminated after 40 min. This element was not subjected to contamination by solids.

Test 107 was performed on an element from which had been removed several sections of varying depths in an effort to visually observe the actual function of the element. This investigation proved impractical due to the poor coalescence and filtration capability of the sectioned element, and the test was terminated after 30 min.

Results obtained in test 113 indicated element defect; the test was terminated after 36 min. The element was sectioned immediately after the test and found to have a partially broken end cap. Large amounts of AC dust were visible at the site of the break, and it was apparent that significant amounts of test-fuel contaminants were passing through the element at this point.

The element used in test 225 exhibited generally satisfactory performance during the test: maximum solids content 0.16 mg/ℓ, maximum free water content 8 to 9 mg/ℓ and maximum Totamitor reading 1. Post-test examination revealed a longitudinal split (about 10 in. long) along the line of mold conjunction.

In test 229, element performance was satisfactory except for passage of excessive free water (16 to 17 mg/ℓ) at the end of the test. Post-test examination revealed a large bulge at one end of the element.

Of the aforementioned seven elements, five exhibited defects which are considered to be manufacturing defects; all were Filters Inc elements. At least 233 Filters Inc elements were used in this program and, thus, the percentage of observed and recorded defective elements is 2.1%. However, it is believed that some obviously defective elements were discarded without being tested and without being recorded. Hence, the percentage of defective elements was probably higher than given above. Of the elements of other manufacturers, the number tested was insufficient to provide any information on the incidence of defects.

14. Repeatability of Filter-Separator Tests

A question of great interest in filter-separator testing is the following: How repeatable are the filter-separator test results? An attempt will be made to answer this question by using results from the most replicated combinations of test conditions. Four groups of tests having nine or more replicate tests are identified in Table 79. Means and standard deviations for nine different performance parameters from these tests are also given in Table 79 along with the boundaries which would include either 95% or 50% of the test results. The 95 and 50% boundaries were calculated as 1.96 X SD and 0.675 X SD, assuming that the distributions of the measurements are normal. The results in Table 79 give a fairly good indication of the repeatability obtained in the AI/SS loop tests and should provide an estimate as to the sort of repeatability one might expect in similar tests run in the future.

TABLE 79. REPEATABILITY SUMMARY FOR PERFORMANCE PARAMETERS

	Element wt gain, g	% dirt load		AEL rating, mg/ℓ		Solids, mg/ℓ		Tot reading	
		20 psi	40 psi	Avg	Max	Avg	Max	Avg	Max
Fuel A, element FI 286, Procedure 10, no. of tests 15*									
Mean	195	87	99	2	2	0.04	0.08	0	0.8
SD	30.3	16.5	17.1	2	3.2	0.04	0.10	0	1.5
95% boundaries	136-254	55-119	66-132	0-5.9	0-8.3	0-0.12	0-0.28	0-0	0-3.7
50% boundaries	174-216	76-98	88-110	0.7-3.3	0-4.2	0.01-0.07	0.01-0.15	0-0	0-1.8
Fuel A, element FI 440, Procedure 10, no. of tests 9*									
Mean	209	91	110	2	4	0.05	0.11	0	1
SD	38.6	21.4	22.2	1.4	2.3	0.05	0.10	0	1.8
95% boundaries	134-284	49-133	66-153	0-4.7	0-8.5	0-0.15	0-0.31	0-0	0-4.5
50% boundaries	183-235	77-105	95-125	1.1-2.9	2.4-5.6	0.02-0.08	0-0.30	0-0	0-2.2
Fuel B, element FI 465, Procedure 13-A, no. of tests 9*									
Mean	240	115	120	10	19	0.10	0.20	0	1
SD	50	25	24	4	5	0.04	0.12	0	1
95% boundaries	142-338	66-164	73-167	2-18	9-29	0.02-0.18	0.00-0.44	0-0	0-3
50% boundaries	206-274	98-132	104-136	7-13	16-22	0.07-0.13	0.12-0.28	0-0	0-2
Fuel C, element FI 465, Procedure 13-A, no. of tests 9*									
Mean	239	116	121	21	45	0.17	0.32	1.9	11.0
SD	73	37	39	16	41	0.05	0.11	2.8	18.7
95% boundaries	96-382	43-189	45-197	0-52	0-125	0.07-0.27	0.10-0.54	0-7.4	0-47.7
50% boundaries	190-288	91-141	95-147	10-32	17-73	0.14-0.20	0.25-0.39	0-3.8	0-23.6

*Fuel identification: A. JP-5 + 16 lb/Mbbl Snt + 0.15% FSII.
B. Clay-treated JP-5 + 16 lb/Mbbl AFA + 0.15% FSII.
C. Clay-treated JP-5 + 20 lb/Mbbl RP + 0.15% FSII.

The data in Table 79 can also be used to calculate the estimated number of tests required to establish that differences in parameter means for two groups of tests are significant at whatever level desired. It should be understood that the results of such calculations are estimates and serve only as guides during the experiment planning stage. More exact calculations to determine level of significance would have to be made using the test data, thus providing a more accurate measure of the standard deviation of the new groups of tests. Suitable equations for these calculations are given in Reference 10.

Suppose that it is desired to determine if there is any difference between the percent dirt load at 40 psi for JP-5 + 16 lb/Mbbl Snt + 0.15% FSII and that for JP-5 containing, a new corrosion inhibitor, using Procedure 10 with Filters Inc elements in both sets of tests. How many tests would be required to detect a difference of 10% in dirt holding capacity that would be significant at the 5% level? In order to calculate the required number of tests, it will be assumed that the standard deviations of the parameters of both groups of tests are the same. For this example, the standard deviation of the percent dirt load at 40 psi for JP-5 + 16 lb/Mbbl Snt + 0.15% FSII run according to Procedure 10 is 17.1%.

The required number of tests can be determined by the equation[10]

$$n = (u_\alpha + u_\beta)^2/D^2$$

where $D(= \delta/\sigma)$ is the difference it is important to detect, expressed as a multiple of the standard deviation, and u_α and u_β are the deviates of the normal curve which cut off single-tailed areas of α and β. The terms α and β, respectively, represent the risks of asserting a significant difference when none exists and asserting that no difference exists when in fact there is a difference of sufficient magnitude to be of practical importance.

The equation given above is for testing one-sided differences; that is, one of the means will always be greater than the other. For the example under consideration here, the means can deviate in either direction. Hence, a two-sided test is called for. This test can be accomplished by substituting for u_α the deviate corresponding to an area of $1/2\alpha$. The calculations are shown below:

$$n = (u_{\alpha/2} + u_\beta)^2/D^2$$

$$= (1.96 + 1.64)^2/(10/17.1)^2$$

$$= 37.8$$

Thus, 38 tests would be required to detect, with confidence, a difference of 10% between the means of percent dirt load at 40 psi for the two fuel blends.

It is unlikely that 38 single-element loop tests would be run for such a purpose. The table which follows lists other numbers of tests for different values of D.

D	No. of tests
0.5	52
1.0	13
1.5	6
2.0	4

Thus, a suitable number of tests, say 6, will detect a difference of δ = 1.5 (17.1) = 25.6% between the means of percent dirt load at 40 psi for the two fuel blends.

It is also possible to reduce the number of tests required by accepting differences at a higher level of risk (less significance). In the example just cited, the standard deviation is an appreciable fraction (17.1/99) of the parameter. If the test procedures or measurements can be refined to reduce the standard deviation, larger values of D can be used and the required number of tests decreased while still detecting significantly the same difference in means.

15. Suggested Plan for Acceptance Tests

The subject of test repeatability, discussed in the preceding subsection, is closely related to filter-separator element or corrosion inhibitor acceptance testing. A test plan similar to that discussed could be used for acceptance testing. However, another type of test plan, and perhaps a more efficient one, would utilize sequential tests of significance.

A number of sequential test plans for various situations are described in statistics books (for example see Reference 10). Here only one type of plan will be presented as an example of how such a plan might be put into practice.

Suppose that it is desired to develop an acceptance test plan for corrosion inhibitors. For the sake of simplicity, suppose the performance parameter of interest is percent dirt load at 40 psi, that clay-treated JP-5 is the test fuel, and that tests are run according to Procedure 13-A. (The foregoing conditions were all selected merely to illustrate the application of the sequential test plan.)

The sequential method used here involves testing for a difference in mean value when the standard deviation is known[10]. For convenience, a standard deviation of 20 will be used in calculations which follow. The method involves determining the location of two parallel limit lines on a plot of cumulative total of percent dirt load versus number of observations. As testing proceeds, points are plotted and testing continues until a point falls outside the limit lines.

The equations necessary to determine the limits are:

$$h_o = \frac{-b\sigma^2}{\delta}$$

$$h_1 = \frac{a\sigma^2}{\delta}$$

where h_o and h_1 are y-intercepts of the lower and upper boundaries, σ is the known or assumed standard deviation, δ is the difference which it is important to detect, and a and b are terms related to probabilities α and β. The terms a and b are calculated as follows:

$$a = ln\frac{(1-\beta)}{\alpha}$$

$$b = ln\frac{(1-\alpha)}{\beta}$$

The factor α is the probability of asserting a significant difference when none exists (in this example 0.05); and β is the probability of asserting that no difference exists when there is a difference of sufficient magnitude to be of practical importance (in this example 0.05).

The slope of the limit lines is calculated by means of the equation below:

$$s = \mu_o + \frac{1}{2}\delta$$

where μ_o is the standard value (in this case 100) against which observations are compared and δ is the difference which it is important to detect (in this case 10 has been selected arbitrarily). Results of calculations are as follows:

$$h_o = \frac{-b\sigma^2}{\delta} = \frac{-2.94(20)^2}{10} = -117.6$$

$$h_1 = \frac{a\sigma^2}{\delta} = \frac{2.94(20)^2}{10} = 117.6$$

$$s = \mu_o + \frac{1}{2}\delta = 100 + 5 = 105$$

$$a = \ln \frac{1-\beta}{\alpha} = \ln \frac{0.95}{0.05} = 2.94$$

$$b = \ln \frac{1-\alpha}{\beta} = \ln \frac{0.95}{0.05} = 2.94$$

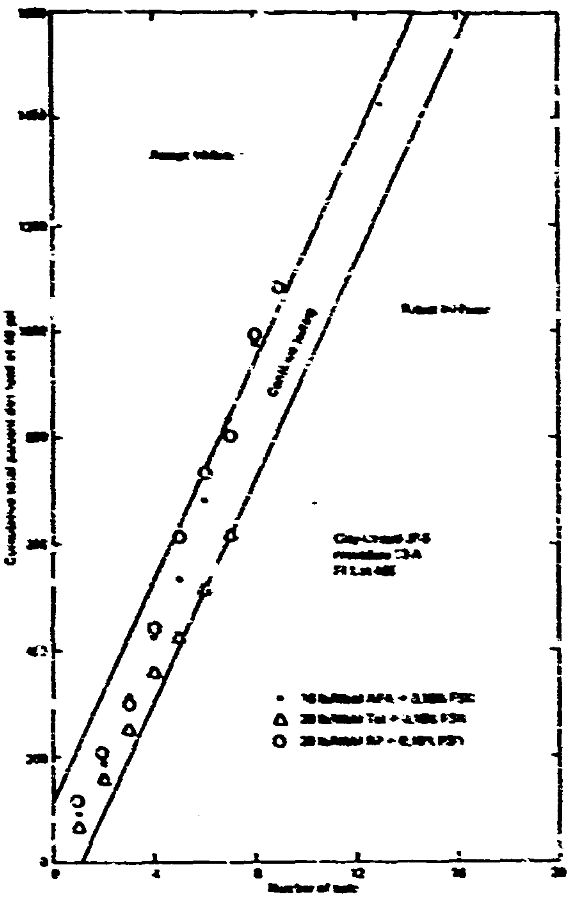

FIGURE 9. EXAMPLE OF GRAPH FOR SEQUENTIAL TEST DECISIONS

The resulting limit lines are shown in Figure 9, along with data plotted for tests on three different corrosion inhibitors but on the same elements and according to the same procedure. In Figure 9, two corrosion inhibitors are indicated as being accepted whereas the third is on the verge of being rejected. The slope and the spacing of the lines are dependent on factors which must be selected, at least initially, by judgment. These factors include the probabilities α and β, the difference δ, and, if it has not been measured, the standard deviation σ.

The foregoing example illustrates the relative simplicity of this sequential test plan. Similar plans and corresponding plots could be prepared for use with any of the performance parameters or for qualification testing of filter-separator elements. This plan is based on the assumption that the standard deviation is known. Somewhat similar test plans have been designed[10] which are applicable where the standard deviation is not known. These plans are slightly more complicated to set up but once in operation a cumulative function of the test data is plotted against number of tests; whenever the plot goes outside the boundaries an accept or reject decision is indicated.

The example just given is meant to be merely indicative of an approach that would provide for an economical and objective method of qualifying filter-separator elements and/or additives. Actual slopes and spacing of limit lines would be best assigned after very careful consideration of the many aspects and ramifications of this type of testing. The data presented in this report, especially the means and standard deviations of data from the most replicated test conditions, can serve as guidelines in formulating sequential or other statistical test designs.

SECTION VI

LOOP TEST CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

Based on the loop test results given and discussed in the preceding section, conclusions are as follows:

- Both WSIM disk stain size and color were appreciably less for fuel blends made up with clay-treated JP-5 than for fuel blends made up with untreated JP-5.

- WSIM disk stain size and color were less for post-test fuel samples than for pre-test fuel samples.

With respect to the effect of amount of injection water used in a test on fuel quality parameters, conclusions are as follows:

- Negative correlation was obtained between post-test FSII concentration and amount of water injected, i.e., FSII concentration decreased as the amount of water injected increased.

- Positive correlation was obtained between post-test WSIM and amount of water injected, i.e., WSIM values increased as the amount of water injected increased.

- There was no apparent correlation between either WSIM disk stain color or stain size and amount of water injected.

With regard to correlations between fuel quality parameters (WSIM and IFT) and element performance parameters, conclusions were as follows:

- For tests grouped according to test procedure, additive and additive concentration, fuel type, and element lot, correlation between pre-test WSIM and any of nine performance parameters was poor. Where slight correlation was implied, the sign of the correlation coefficient was opposite to what would be expected. For the same groups of tests, there was no indication of correlation between pre-test IFT and any of the element performance parameters.

- For tests grouped only according to fuel type and element lot, somewhat better correlation was obtained between pre-test WSIM and four performance parameters (percent dirt load at 40 psi, average AEL rating, average solids content, and average Totamitor reading). Also, the signs of the correlation coefficients were, generally, as would be expected. For the same groups of tests, correlation between pre-test IFT and the aforementioned four-element performance parameters was better than for the more restricted test groupings.

- No correlation was obtained between WSIM and IFT values for tests grouped according to fuel type, additive, and FSII concentration.

- Significant positive correlation was obtained between pre-test WSIM and pre-test IFT when data from tests on fuel without corrosion inhibitors were added to each group of tests described in the preceding paragraph.

With regard to the effects of clay treatment of fuel on fuel quality parameters and on performance of filter-separator elements, conclusions are as follows:

- Clay treatment caused a significant increase in the WSIM of uninhibited JP-5.

- Fuel blends prepared with clay-treated JP-5 had higher WSIM values than did similar blends prepared with untreated JP-5.

- Clay treatment had no effect on the level of IFT of JP-5 fuel, either uninhibited or as blended with additives.

- During sequences of tests on fuel containing corrosion inhibitor, followed by clay treating, and reblending with corrosion inhibitor, clay treating was more effective in restoring high WSIM levels than high IFT levels.

- There was no evidence that clay treatment reduced the variability of WSIM or IFT values of JP-5 fuel, either uninhibited or as blended with additives.

- Clay treatment does cause FSII to be removed from JP-5 fuel; the amount removed is small and gradually decreases with successive uses of the clay canisters.

- When fresh clay canisters are used, clay treatment removes all the color bodies from JP-5, but in the course of additional blending with corrosion inhibitors, testing, and clay treatment, fuel color increases, becoming essentially constant after 6 or 7 clay treatments.

- There was no evidence that clay treatment significantly improved the performance of filter-separator elements nor that it significantly reduced variability in the measured performance parameters.

With regard to the effects of variations in injection water quality on element performance parameters, there was no evidence that observed variations in water surface tension, solids content, or pH had any effect on measured performance parameters.

With regard to the effect of variations in element physical parameters (element weight, element differential pressure in the pressure-check trough, and element differential pressure at the start of testing) on element performance parameters, conclusions are as follows:

- There was no evidence of significant correlation between any of the three element physical parameters and any of the element performance parameters.

- Correlation between pairs of the three element physical parameters was generally very poor for tests grouped according to element lot, test procedure, fuel type, and additives and additive concentration.

- Very highly significant positive correlation was obtained between all pairs of element physical parameters when all six lots of elements from one manufacturer (Filters Inc) were considered together.

The results of a group of tests involving three different corrosion inhibitors (AFA-1, Santolene C, and Lubrizol 541) and elements from four manufacturers (Filters Inc, Fram, Bendix, and Bowser) indicated the elements could be ranked in the order of decreasing effectiveness as follows: (1) Filters Inc, (2) Bendix, (3) Bowser, and (4) Fram. The corrosion inhibitors could be ranked in order of increasing detrimental effect as follows: (1) AFA-1, (2) Santolene C, and (3) Lubrizol 541.

On the basis of another group of tests run according to Procedure 13-A, using Filters Inc elements of a single lot, and clay-treated JP-5 plus 0.15% FSII plus one or another of six corrosion inhibitors, it was possible to rank the corrosion inhibitors in order of increasing detrimental effect as follows: (1) AFA-1, (2) RP-2, (3) Tolad 244, (4) Santolene C, (5) Unicor M, and (6) Lubrizol 541.

The foregoing rankings of both filter-separator elements and corrosion inhibitors are based solely on test results presented herein. Hence, the rankings are not inferred to be universally applicable. Using other test conditions, test procedures, and other batches of filter-separator elements and corrosion inhibitors the order of ranking might be different.

Rather limited test results suggest that 0.15% FSII in JP-4 or JP-5 (either untreated or clay-treated) causes a slight decrease in the fuel's WSIM value. No appreciable effect of FSII on IFT values of JP-4 or JP-5 was noted.

The extent of correlation between ten pairs of element performance parameters, based on results from tests having the same fuel type, additive and additive concentration, FSII content, and element lot, was determined and a

noticeable trend in correlation was observed in only four cases: average AEL rating vs average Totamitor reading, positive correlation, average Totamitor reading vs percent dirt load at 20 and at 40 psi, negative correlation; and maximum Totamitor reading vs maximum AEL rating, positive correlation.

Very highly significant positive correlations between Totamitor readings and corresponding AEL ratings and solids contents were obtained when data from all tests were lumped together without regard to test conditions.

Using results from tests grouped according to fuel and corrosion inhibitor, there was good positive correlation between average Totamitor reading and the sum of average AEL rating and average solids content. With all grouping restrictions removed except type of fuel, very highly significant positive correlations were obtained between average Totamitor readings and the sum of average AEL rating and average solid content, both for JP-4 and JP-5 fuel.

The general, but not extremely conclusive, indications provided by comparison of test procedures were that element performance was poorer with finer solid contaminants.

2. Recommendations

On the basis of test results and experience derived from the Al/SS loop tests reported herein, a number of recommendations have been formulated relative to test planning, test equipment, test procedures, test materials, and areas for future study.

With regard to test planning, one recommendation is foremost. Test plans should be designed so that the inferences drawn from the data can be subjected to statistical tests of significance. It is believed that the statistics (means, standard deviation, etc.) reported herein can be used as guidelines in selecting numbers of replicate tests such that differences in performance of elements of different lots or of different additives can be assessed at any desired level of significance. Statistical test plans, particularly those based on sequential tests of significance, are recommended as being most satisfactory for acceptance testing of filter-separator elements or corrosion inhibitors.

The overall utility of these tests can be increased, in general, in three ways: by increased replication of tests, by reducing variability in test materials (filter-separator elements, fuels, and additives), and by reducing variability of parameter measurements (free water content, solids content, differential pressure, etc.).

Increased test replication can be effected by limiting the number of test procedures, element lots, and fuel blends.

Variability in filter-separator elements could be reduced by eliminating those elements which deviate markedly from the mean of appropriate element-quality parameters. At present there are only two easily measured, nondestructive measures of element quality, namely, weight and element differential pressure. The establishment of other easily measured, nondestructive, and meaningful element quality parameters would aid in reducing element variability and, hopefully, provide additional parameters which might correlate with element performance.

There appears to be little hope of significantly reducing fuel variability from that experienced in these tests. About all that can be recommended is that a sufficient supply of a given batch of fuel be on hand to permit running all of the test groupings in a study of some factor or variable. Some reduction in fuel variability over a long period of time might be effected by the use of storage tanks made of corrosion-resistant metals such as aluminum or stainless steel.

A change in clay-treatment procedure might also result in increased uniformity of test fuel over a period of time and also permit running tests with various additives on a random basis. The new procedure would entail clay treating 600 gal of test fuel, blending with additives, running one test, and pumping the fuel to a second storage tank. Each test would therefore be run with fresh clay-treated fuel, and additives could be different for successive tests. An additional advantage of this clay-treating procedure is that the test fuel is not being continually water washed. Also, there is no possibility of a buildup in the fuel of nonadsorbable constituents from the additives. Such a buildup could occur using the present clay-treating procedure, in which additive is removed after each test by clay

treating the test fuel. It is assumed that clay treating removes all the corrosion inhibitors, and, on this basis, fresh additive and makeup fuel are added prior to each test. The validity of this assumption is open to serious question. In a series of 10 or 12 tests on fuel with the same additive, it is very possible to have a buildup of those constituents which are less adsorbable. An indication of such preferential buildup is afforded by the fact that, in the tests reported herein, JP-5 fuel was rendered colorless ("water-white") by initial clay treatment; but with successive cycles of blending with corrosion inhibitors, testing and retreating, the fuel reverted to its normal yellow color.

With regard to maintaining uniformity of additives over a long period of time, it is suggested that ample additive be obtained prior to start of a test program and that additive storage should be such that deterioration of the additive is minimized. For example, certain corrosion inhibitors are not homogeneous, and the insoluble constituents settle out; this could be prevented or minimized by subzero storage. Such storage would also minimize solvent evaporation losses.

The variability of measured element-performance parameters can possibly be reduced in some cases as discussed in the following paragraphs.

Some reduction of the variability in free water content as indicated by the AEL free water detector method might result from the development of an electronic, automatic device for rating AEL pads. Variability in measured solids contents could be decreased if improved membranes were available. The currently used membranes are adversely affected by free water in the fuel. This may account, in part, for the frequent indications of negative solids contents.

It seems possible that more quantitative information might be derived from Totamitor readings. Correlations between Totamitor readings and fuel contaminant content could be obtained for free water and for each type of solid contaminant used. These correlations could be sought at conditions (fuel temperature, pressure, and flow rate) generally used in these tests. It is anticipated that the Totamitor or other instruments based on optical measurements can never be highly quantitative because of the effects and interactions of factors such as turbulence, fuel additive content, and combinations of water and solids contaminants. However, it does appear possible to increase the utility of the Totamitor readings taken with the same instruments, under uniform test conditions, and using a limited number of known solid contaminants. For purposes of economy, the foregoing Totamitor correlation experiments could be run in conjunction with correlation of dirt-feed systems.

The effects of various additives, as well as correlations between fuel quality parameters such as WSIM and IFT and between fuel quality parameters and element performance parameters, could all be studied in a program wherein tests were run using additive-fuel blends ranging from zero additive concentration to the maximum allowable, or even higher, additive concentration. Such a program should provide a wide enough range of data to permit detection of any real correlations between the various fuel quality parameters and element performance parameters.

Additional information about filter-separator element performance might be provided by a standard method of dissecting, examining, and assigning quantitative ratings of elements after testing.

The effects of element physical parameters such as weight or density could be studied by using specially fabricated elements. These would be fabricated from single lots of raw material and by a single manufacturing procedure, but the amount of raw material in the individual elements could be varied in a controlled manner.

SECTION VII

SMALL-SCALE COALESCENCE STUDIES

1. Introduction

The ability to coalesce free water in fuel is one of the most important functions of a filter-separator element. Yet, the mechanisms of coalescence are not well understood and the development of filter-separator elements which effectively coalesce water has apparently proceeded on an empirical basis. A more complete understanding of the mechanisms and factors involved in coalescence should make possible a more rational approach to filter-separator element design and eventually filter-separator elements with improved water-coalescing capabilities.

The methods of studying coalescence phenomena range from very fundamental investigations involving detailed observations of individual water droplets and sites of coalescence to the fabrication and testing of full-size elements.

Neither of the two extremes of experimental method was suited to the facilities or personnel available for studying coalescence under this program. Consequently, an intermediate approach which might be termed a "small-scale empirical" study was undertaken.

It was elected at the outset to study coalescence only, reserving the study of complications resulting when coalescence and filtration occur simultaneously in the media bed until such time as the coalescence phenomena were more fully understood. The effect of variations in coalescence media parameters (media thickness and density) was the subject of the work reported herein. An experimental apparatus was designed and fabricated which provided controlled, once-through flow of fuel and water, a means of dispersing water in the fuel, a cell which contained coalescence media, a fallout chamber for observation of coalesced water drops, and a means of detecting free water content of the effluent fuel.

2. Experimental Apparatus, Materials, and Techniques

a. Apparatus

Before describing in detail the small-scale coalescence apparatus used in the experiments reported herein, examination of the design considerations will be useful.

Versatility was one of the primary design considerations. An apparatus was desired which would permit the controlled variation, over wide ranges, of the parameters of importance to coalescence of water from fuel. These parameters include those pertaining to the coalescing media, the fuel, injection water, and flow conditions.

Coalescence media parameters of importance are as follows:

Material

Particle size (fiber diameter, particle mean diameter, or other suitable measure)

Pore characteristics (dimensions, distribution)

Density

Thickness

All of these parameters are interrelated and are primarily characteristics of the media itself. The media used in these experiments will be described in the following section of this report. Media thickness is the only one of the aforementioned parameters that is directly dependent on apparatus design.

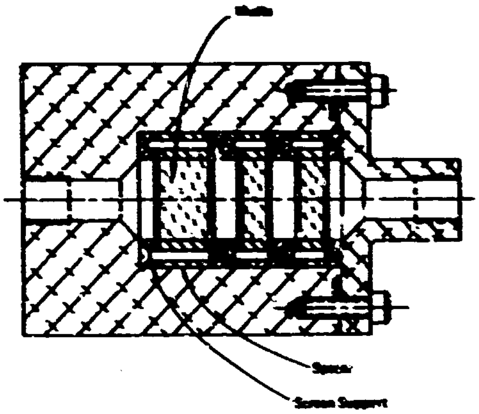

FIGURE 10. COALESCER CELL ASSEMBLY

The coalescence cell, shown in Figure 10, was designed to accommodate a wide range of media thicknesses and, also, to permit the use of several layers of different media, with independent control of the thickness and density of each layer. A variety of spacers and screen supports make possible the testing of media in thicknesses ranging from 1/16 to 1 in., in 1/16-in. increments. Also, several media layers of various thicknesses, with the layers seperated or contiguous, can be tested.

Several alternate designs, differing both in principles and details, were considered at various stages in the development of the apparatus. One of the principal differences in these designs was the means of driving the fuel and injection water. The two test fluids can be driven either by pump or gas pressure or by combinations of the two.

The use of a pump has three disadvantages. Pressure fluctuations are associated with certain types of pumps, for example, piston pumps. The generation of frictional heat within the pump may be troublesome in some cases. Wear debris from the pump might affect the coalescence characteristics of the media. The later problem would be more serious in tests where filtration was being evaluated.

Gas drive systems have none of the undesirable attributes just described for pump systems, but instead, a more serious drawback, at least for this application. At any point in the system where the pressure is substantially less than the driving gas, bubbles will be formed by gas evolution.

In a coalescence test apparatus such as the one being described, the bubble release region is likely to be in the coalescence media, which would affect the coalescing process, or at the system exit, in which case the bubbles might interfere with the determination of the free water content of the effluent fuel. As will be seen later, the system selected uses low-pressure helium to drive the fuel and the water to a pump-type homogenizer which provides the pressure needed to force the fuel-water mixture through the system.

Another major function of the apparatus which can be performed in several ways is that of dispersing the free water. In principle, three methods are feasible: stirring or other mechanical agitation, agitation by ultrasonic vibrations, and dispersion by fluid turbulence such as that present in and immediately after an orifice. The apparatus selected for the combined functions of water dispersion and fuel pumping was a Manton-Gaulin Laboratory Homogenizer, Model 15M-8TA which combines a single-piston, high-pressure, 15-gph pump and an adjustable orifice.

The version of the small scale coalescence apparatus used in these tests is shown in Figure 11. Helium pressure (20 psi) was used to drive the fuel up to the inlet of the homogenizer. Helium pressure (40 psi) was also used to drive the injection water up to the homogenizer inlet. Details of the fuel and water entry arrangements are shown in the Figure 11 inset. A rotameter was used to measure water flow rate. The inlet fuel flow rate was that of the homogenizer pump (0.25 gpm). An accumulator connected to both the fuel and water lines served to damp out pump-induced flow fluctuations and permit measurement of water injection rate. Another accumulator, just downstream of the homogenizer, limited pressure fluctuations to ± 1 psi at the coalescer cell inlet.

The homogenizer is designed to operate with high differential pressures across the orifice, on the order of 500 to 4000 psi. In the early stages of equipment checkout, it was found that normal operation of the homogenizer resulted in pressure and flow pulsations that were very difficult to smooth out, as well as excessive heating of the fuel and extremely fine dispersion of the water in the fuel. Subsequently, the homogenizer pressure was held to about 100 psi, which improved the operation considerably.

Test fuel temperature was regulated by means of a manually controlled, water-cooled, concentric tube heat exchanger downstream of the outlet accumulator. After the heat exchanger, the fuel-water mixture was divided

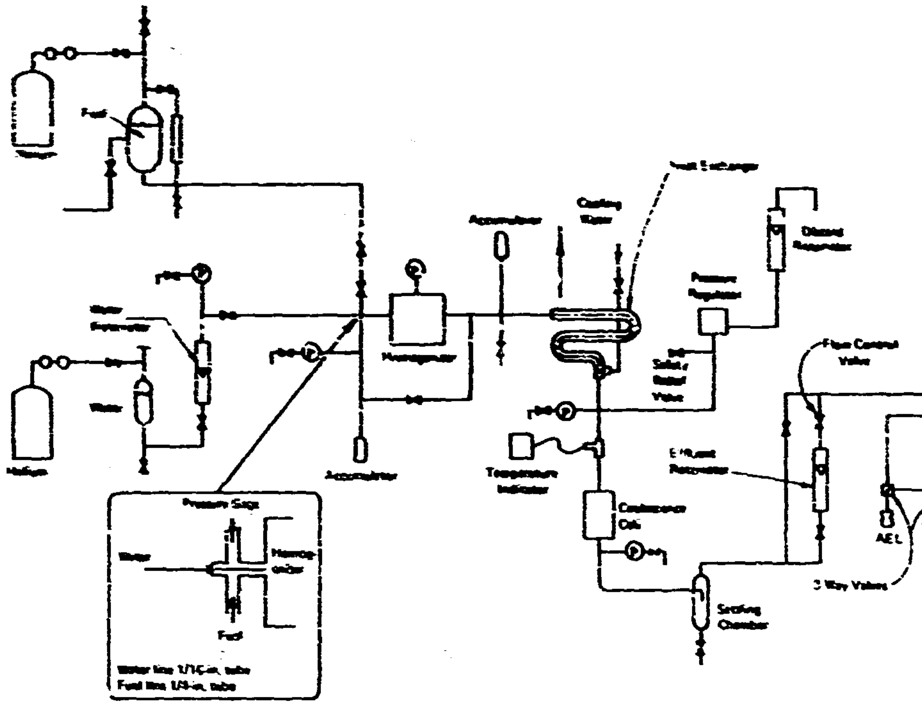

FIGURE 11. FLOW PLAN OF SMALL-SCALE COALESCENCE APPARATUS

into two streams.* Four-fifths of the mixture was diverted through a discard line. Mounted in the discard line was a safety relief valve and a back-pressure regulator. Flow rate through the discard line was monitored by a rotameter but was not controlled.

The test fuel-water mixture, the remaining one-fifth of the mixture, passed through the coalescer cell and into the transparent settling chamber. Flow rate of the test fuel-water mixture was controlled by means of needle valves downstream of the settling chamber. In all tests reported herein, the flow rate through the test section was 189 ml/min (0.05 gpm). Coalesced water was collected in the settling chamber. Fuel and any uncoalesced water passed out the top of the settling chamber, through a rotameter, and then either through a discard line or an AEL pad holder. The coalescer and settler were held under pressure (downstream flow regulation) to avoid gas evolution in these sections.

The major components of the small-scale coalescence apparatus are more fully identified as follows:

- Two-stage helium regulator, 100-psi outlet, Harris Calorific catalog No. 92-100A-590
- Two-stage helium regulator, 250-psi outlet, Harris Calorific catalog No. 92-250A-590
- Fuel reservoir, 15-gal, 316 stainless steel
- Water reservoir, 150-ml, 316 stainless steel
- Manton-Gaulin 15-gph laboratory homogenizer, Model 15M-8TA

All plumbing, valves, and rotameter parts making contact with either the fuel or injection water were of stainless steel.

*This flow plan, with split stream of fuel-water mixture, was adopted because the homogenizer would not operate without overheating at the low flow rates required by the coalescer section. This problem exists with most laboratory homogenizers and mills. The split-stream system also provides a convenient means for supplying fuel-water mixture at constant pressure to the coalescer cell.

b. **Materials**

Materials used in these tests include fuels, injection water, and coalescence media.

Test fuels were used as follows:

Test No.	Fuel
1, 2	Uninhibited JP-5, not further identified
3-21	Uninhibited JP-5 (Batch 23)
22-25	Bayol R-34
26-112	Uninhibited JP-5 (Batch 24)
113-127	Uninhibited JP-5 (Batch 25)

Distilled water was used as the injection water in all the small-scale coalescence tests.

A variety of coalescence media was used in exploratory tests (first 41 tests), as follows:

Coarse WSIM disks
Fine WSIM disks
Filter-separator middle section (Filters Inc)
Standard steam pipe insulation
Unidentified glass fiber sheet
Babcock - Wilcox Kaowool
Glass fiber roof insulation, Johns-Manville
Glass wool
Fentron A+ polypropylene felt
Complete plug from filter-separator element (Filters Inc)
Steel wool
Filter-separator sock material
Whatman filter paper

In tests 42 to 127, only three types of "Fiberglas®" media were used as follows:

Fiberglas® designation	Fiber dia, in.	Thickness, in.	Original mat characteristics: Surface density, lb/ft_2	Density, lb/ft^3
FM 003	0.00003	1/4	0.010	0.48
FM 011	0.00011	1/4	0.012	0.57
FM 018	0.00018	3/16	0.016	1.01

These media are described by the manufacturer (Owens-Corning Fiberglas Corp) as high-efficiency filtration media composed of fine glass fibers bonded with a thermosetting resin.

In tests 42 to 127, the final compressed density of the media in the coalescer cell was controlled. In most tests, one of three densities was used: 4, 8, or 16 lb/ft^3. Desired densities were achieved by using enough small circular disks to provide the proper weight of media for the desired thickness and density.

c. **Procedure**

The sequence of procedures used in preparation for a test in the small-scale coalescence apparatus was as follows:

- Clean apparatus and components
- Install media in coalescer cell
- Pressure check coalescer cell
- Assemble apparatus
- Charge reservoir with fuel
- Start fuel flow
- Start water injection and start test

Before starting a test, the coalescer cell was removed from the apparatus and cleaned by rinsing with isopropanol, then with acetone, and then air dried. The settling chamber was cleaned by rinsing with isopropanol and then with test fuel.

In tests up through test 42, the lines were cleaned by pumping isopropanol and then fuel through the lines. From test 43 through test 127, the lines were cleaned by draining after a test and then pumping test fuel through the system for 10 min and then taking 500-ml AEL samples to assure that the free water ratings were 0 to 1 mg/liter or less.

Disks of 0.76-in. diameter were cut from the sheet filtration media by means of a circular punch. In order to obtain the specified media density for a given test, the number of disks providing the proper weight were packed into a spacer of the proper length. The media were held in place by screen supports fastened to each end of the spacer.

The airflow resistance of the media, in position in the coalescer cell, was measured at an airflow rate of 8 liters/min. in a calibration setup similar to that used for quality control on ASTM separometer coalescer disks.

In tests 35 to 127, the 15-gal fuel reservoir was charged from a 55-gal lined steel drum by means of air pressure. The drum was charged, as needed, by means of the pumping system used to bring fuel from the storage tanks in to the Al/SS loop. Before entering the drum, the fuel passed through a filter-separator unit. In order to minimize the danger of picking up water in the drum, the drum was usually filled at the end of the day to take advantage of overnight settling. Also, the end of the filling tube was about 2 in. above the bottom of the drum. A similar arrangement was provided in the 15-gal reservoir on the small-scale coalescence apparatus. The end of the outlet line was approximately 2 in. above the bottom of the reservoir. In addition, the reservoir was periodically emptied through a drain at the low point in the reservoir.

The majority of the tests were of 20-min duration, and the usual procedure was as follows.

- After starting fuel flow, a 500-ml AEL sample was drawn to assure that no free water was present in the fuel.
- Water injection at 0.00025 gpm (0.1% of fuel flow through homogenizer) was started.
- AEL ratings were then taken at 5-min intervals (tests were terminated whenever two successive ratings of 20+ or higher occurred).

With regard to AEL ratings, sample volumes of less than 500 ml were frequently taken (usually 200 ml) in an attempt to provide a quantitative measure of free water content where coalescence was poor. AEL data from the small-scale coalescence tests have been adjusted for sample volume in accordance with the correction factors given in an earlier report[6]. Correction factors for the sample volumes used in the small-scale coalescence work are listed below:

Sample size, ml	Correction factors
200	1.50
300	0.92
400	0.74
500	0.56

All AEL data given in this section on small-scale coalescence tests have been corrected for sample volume, except where noted.

3. Test Results and Discussion

Five groups of tests were run in the small-scale coalescence studies as follows: two groups of exploratory tests; a group of tests to study effects of media parameters on coalescence; a group of tests to evaluate a gas-drive, orifice-disperser system; and a group of four tests on two-layer media.

The first group of exploratory tests served to iron out rig and operational problems and to provide an indication that the major problem in the small-scale coalescence tests would be obtaining quantitative ratings of effluent free water content. A variety of coalescence media was tried in 24 tests; none coalesced water effectively enough to provide free water ratings below 17 mg/ℓ, using 500-ml samples (10 ml/ℓ corrected rating). Test conditions were as follows: Homogenizer pressure 75 to 135 psi, coalescer cell inlet pressure 70 psi, test fuel flow rate 189 ml/min, water injection rate 0.1% of fuel flow rate, and test fuel temperature in the range of 63 to 86°F, with most tests in the 78 to 82°F range.

Effluent free water content was so high that it was impossible to get AEL free water ratings in most tests. Therefore, visual comparison was used to provide a relative rating of free water content. Samples collected from the discard line with various rates of water injection were used as the standards:

Water injected, mg/ℓ	Rating
34	0
64	1
122	2
197	2
306	3
429	4
1000	4

During a test, fuel samples from the discard line and from the test cell outlet were collected in separate test tubes and compared to give a rating for the test-cell effluent.

Although the method provides only a qualitative rating of free water content, it was possible to show that appreciable differences in coalescing ability existed among the various media. The results of these first 24 exploratory tests are presented in Table 80. One of the most significant conclusions from these tests is that all media caused some coalescence. In all tests, effluent fuel tube ratings were lower than discard fuel tube ratings (these were 4 in all

TABLE 80. INITIAL EXPLORATORY SMALL-SCALE COALESCENCE TESTS

Homogenizer pressure: 75-135 psi
Water injection rate: 0.1%
Test cell inlet pressure: 70 psi
Test cell inlet temperature: 63°-86°F

Test no.	Fuel	Media	No. of disks	Thickness, in.	Settling chamber appearance	Uncorrected AEL rating,* mg/l	Effluent test tube rating
2	JP-5	Fine (red) WSIM	8	1/4			
3	JP-5	DOD middle wrap	1	1/4	Very cloudy	Washed out 5 min	–
4	JP-5	Fine (red) WSIM	8	1/4	Cloudy	Washed out 5 min	–
5	JP-5	Steam wrap (used)	2 in. uncompressed	1/2	Clear	20+	0 at 5 min
6	JP-5	DOD middle wrap	2	7/16	Clear with small droplets	20 at 15 min	1 at 10 min
7	JP-5	Insulation, unidentified	3	1/2	Clear with small droplets	–	1 at 8 min
8	JP-5	Wool blanket 1/4" 8 lb/cu ft	6	1/2	Clear with small droplets	–	1 at 5 min
9	JP-5	DOD element plug	1 plug	1/2	Cloudy	–	1 at 3 min
10	JP-5	1 fine WSIM disk & 2" of uncompressed steam wrap (used)	note media	1/2	Slightly cloudy	17-20 at 20 min	0 at 5 min
11	JP-5	1 fine WSIM disk & 2" of uncompressed steam wrap (unused)	note media	1/2	Cloudy	–	2 at 5 min
12	JP-5	4-5/8" of fiber-glass roof insul.	note media	1/2	Slightly cloudy	–	1 at 5 min
13	JP-5	Medium glass wool	Hand packed	1/2	Very cloudy	–	3 at 5 min
14	JP-5	Polypropylene felt	2	7/16	Cloudy	–	3 at 5 min
15	JP-5	One fine WSIM disk & 1/2" used steam pipe wrap + 8 coarse WSIM disks	See media	1/2 + 1/2	Slightly cloudy	–	1 at 5 min 2 at 16 min
16	JP-5	One fine WSIM disk, 2" used steam pipe wrap, and 8 coarse WSIM disks	See media	1	Fine cloudy streaks	–	0 at 5 min
17	JP-5	Special test for establishing approximate water contents for tube ratings.					
18	JP-5	Filters Inc element plug with sock	See media	3/4	Cloudy	–	2 at 15 min
19	JP-5	Filters Inc element plug with sock	See media	3/8	Slightly Cloudy	–	1 at 5 min
20	JP-5	Special test with variable fuel flow rate - described elsewhere.					
21	JP-5	Special test with variable fuel flow rate - described elsewhere.					
22	Bayol R-34	One fine WSIM disk & 2" steam pipe wrap	See media	1/2	Slightly cloudy	–	1 at 5 min 1 at 10 min
23	Bayol R-34	8 fine and 8 coarse WSIM disks, alternating	See media	1/2	Slightly cloudy	–	1 at 5 min 1 at 15 min
24	Bayol R-34	Two fine WSIM disks, 891 mg steel wool, 2 coarse WSIM disks	See media	1/2	Slightly cloudy	–	1 at 5 min
25	Bayol R-34	One fine WSIM disk & 2" uncompressed used steam pipe wrap	See media	1/2	Slightly cloudy	–	0-1 at 5 min 0-1 at 10 min

*500-ml sample.

tests). Also, in several tests, effluent ratings of less than 2 were obtained. These results indicate that media exist which can coalesce significant amounts of free water under the conditions used. Two areas for further study seemed evident on the basis of these initial experiments: (1) development of a more quantitative free water rating method for a wide range of conditions and (2) a systematic study of the effects of media parameters on coalescence.

It was decided to study three glass fiber media parameters: fiber diameter, media density, and media thickness. Each parameter was to be studied at three levels. However, before this test program was started, an additional series of exploratory tests was performed, mainly to see if sufficient coalescence could be obtained to permit use of the AEL free water detection method in conjunction with smaller AEL sample sizes. Results of these tests are summarized in Table 81.

TABLE 81. SECOND SERIES OF EXPLORATORY SMALL-SCALE COALESCENCE TESTS

Fuel: JP-5 Homogenizer pressure: 70-100 psi Water injection rate: 0.1%
Test cell inlet pressure: 70 Test cell inlet temperature: 65° to 78°F

Test no.	Media	Thickness, in.	AEL rating,* mg/l
26	One fine and one coarse WSIM disk	1/16	20+++ at 8 min
27	Two fine and two coarse WSIM disks	1/8	Below 12 for 27 min
28	Four fine and four coarse WSIM disks	1/4	Below 10 for 24 min
29	Four fine and four coarse WSIM disks	1/4	Below 11 for 20 min
30	Four fine and four coarse WSIM disks plus one course WSIM disk	1/4 + 1/16	20+++ at 11 min
31	Four fine and four coarse WSIM disks	1/4	20+++ at 3 min
32	Four fine and four coarse WSIM disks	1/4	20+++ at 2 min
33	Four fine and four coarse WSIM disks plus cotton sock	1/4	20+++ at 8 min
34	Four fine, four coarse WSIM disks, and one thickness Whatman filter paper	1/4	20+++ at 8 min
35	Four fine and four coarse WSIM disks	1/4	20+++ at 8 min
36	Four fine and four coarse WSIM disks, and one thickness Whatman filter paper	1/4	18-19 at 6 min
37	Four fine WSIM disks, one thickness Whatman filter paper, four coarse WSIM disks	1/4	20+++ at 6 min
38	Four fine WSIM disks, two coarse WSIM disks, one thickness Whatman filter paper, two coarse WSIM disks, and one thickness Whatman filter paper	1/4	20+ at 5 min
39	Four fine and four coarse WSIM disks plus 1 layer of cotton sock	1/4	1 at 17 min
40	DOD element plug	1	4 at 12 min 20+ at 17 min
41	DOD element plug	1/2	10 at 9 min 20+ at 13 min

*Corrected for sample size except for 20+, 20++, and 20+++ ratings.

The review of earlier work and the exploratory runs indicated that the small-scale coalescer apparatus, including the homogenizer, could be used in rating the performance of various coalescence media. The number of parameters involved in studying coalescence media is sizable and includes the following: media form (fibers, particles, porous structure), media material (glass, metals, ceramics, organic compounds, natural fibers, etc.) size and number of openings in media size of particles or fibers, thickness of media, and number of layers (each layer being subject to the same number of parameters).

It was decided to study the effects of three parameters on the coalescing behavior of fiberglass media as follows:

Fiber size (0.00003, 0.00011, and 0.00018 in. dia)
Media density (4, 8, and 16 lb/ft^3)
Media thickness (1/8, 1/4, and 1/2 in.)

The test program was set up as a full-factorial experiment, with duplicate runs at each combination of parameter values.

The results of the tests to study effects of media parameters on coalescence are given in Table 82.

In order to condense these data for examination, an average AEL rating was calculated for each fiber diameter-density-media thickness combination, using all the data in Table 82. In order to make these calculations, 20+, 20++, and 20+++ ratings were arbitrarily assigned values of 30, 50, and 100 mg/ℓ, and sample volume corrections were also applied. The resulting averages are shown in Table 83.

Table 83 also gives overall averages for each density, each thickness, and each fiber diameter. Examination of these averages indicates the following trends:

best density: 16 lb/ft^3
best thickness: 1/4 in.
best fiber diameter: 0.00011

Possibly it is only fortuitous, but the best performance of the 27 fiber diameter-density-thickness combinations was for the 0.00011-in.-dia fiber, 16 lb/ft^3 density, and 1/4-in. thickness combination.

It was originally planned to also study the effects of multilayer media, but time permitted only four tests on two-layer media, see Table 84. The results indicate that coalescence was good in these tests. At least, quantitative AEL ratings (using 200 ml samples) were obtained throughout these tests, indicating that free water contents did not exceed 20 mg/ℓ.

A total of eight tests were run to try out the use of a helium-drive, orifice-disperser system which would not require the use of the homogenizer. Preliminary experiments showed that very fine, uniform water dispersal could be obtained by using pressures of 80 psi and 85 psi to drive the fuel and water, respectively, and a 0.016-in-dia orifice. Test results presented in Table 85 indicate that coalescence was generally very poor in these tests. However, due to the 40- to 60-psi pressure drop across the orifice, many bubbles were present in the fuel downstream of the orifice. It was felt that the bubbles would interfere with coalescence and the orifice-disperser system was abandoned.

The airflow resistance of the media was measured before nearly all tests. This was accomplished in the apparatus regularly used for checking airflow resistance of WSIM discs. The pressure drop across the media was measured at an airflow rate of 8ℓ/min. The pressure drops for individual test media are given in Tables 82 and 85. A plot of logarithm of average pressure drop versus logarithm of density for different media thicknesses and fiber diameters is shown in Figure 12. In all nine combinations of media thickness and fiber diameter, the plots very closely approximate straight lines.

TABLE 82. SMALL-SCALE COALESCER TEST RESULTS

Homogenizer pressure: 70 to 90 psi — Test cell inlet pressure: 70 psi

Water injection rate: 0.1% — Test cell inlet temperature: 66° to 78°F

Test no.	Fiber diameter, in.	Compressed density, lb/ft³	Thickness, in.	Coalescer cell ΔP, psi		Pre-test	AEL rating‡ in mg/ℓ at indicated time (min)			
				Air flow*	Fuel flow†		5	10	15	20
42	0.00003	8	0.50	5.02	20	0	20+++	---	---	---
43	0.00003	8	0.25	2.35	16	0	13	18	---	32
44	0.00003	8	0.12	1.47	10	0	31	---	---	---
45	0.00003	8	0.50	---	18	0	20+	---	---	---
46	0.00003	8	0.25	3.44	14	0	20+++	---	---	---
47	0.00003	8	0.12	2.78	10	0	9	---	---	29
48	0.00018	16	0.50	0.66	14	0	11	13	15	31
49	0.00018	16	0.12	---	3	0	29	18	20+++	---
57-A	0.00018	4	0.50	0.48	3	1	7	7	12	11
58	0.00018	4	0.12	0.10	3	0	20+++	---	---	---
59	0.00018	16	0.25	0.19	4	1	2	6	6	4
60	0.00018	16	0.50	0.58	4	1	1	29	20+	20+
61	0.00018	16	0.25	0.20	4	1	2	6	6	6
62	0.00018	16	0.12	0.14	4	1	15	27	31	20++
64	0.00018	8	0.50	0.15	4	0	12	12	12	12
65	0.00018	8	0.25	0.08	4	0	7	12	23	20+
66	0.00018	8	0.12	0.08	3	0	29	20+	20++	20+++
67	0.00018	8	0.12	0.06	3	0	20+++	20+++	---	---
68	0.00018	8	0.25	0.10	4	0	2	2	2	4
69	0.00018	8	0.50	0.14	3	0	24	20	21	23
70	0.00003	16	0.25	---	43	0	12	15	31	31
71	0.00003	16	0.50	---	64	0	20+++	---	20+++	20+++
72	0.00003	16	0.12	4.98	20	0	12	12	12	29
73	0.00003	16	0.50	---	15	0	20+++	---	---	---
76	0.00018	8	0.50	0.15	4		9	7	10	10
77	0.00018	8	0.12	0.08	3	0	20+++	20+++	---	---
78	0.00018	8	0.25	0.08	3	0	8	12	15	29
79	0.00018	8	0.50	0.13	3	0	29	27	27	27
80	0.00018	8	0.25	0.07	4	0	1	2	2	4
81	0.00018	8	0.12	0.03	3	0	20+++	---	---	20+++
82	0.00018	4	0.50	0.06	3	0	---	12	12	12
83	0.00018	4	0.12	0.01	3	0	20+++	---	---	---
84	0.00018	4	0.25	0.03	3	0	30	31	20+	20+++
85	0.00018	4	0.50	0.06	4	0	13	15	13	13
86	0.00018	4	0.25	0.03	3	0	30	20+	20++	20+++
87	0.00018	4	0.12	0.02	3	0	20+++	---	---	20+++
88	0.00018	4	0.50	0.05	3	0	20+++	20+++	---	20+++
89	0.00018	4	0.12	0.01	3	0	20+++	20+++	---	20+++
90	0.00018	4	0.25	0.02	4	0	20+++	20+++	20+++	20+++
91	0.00018	4	0.50	0.04	3	0	10	24	31	20+
92	0.00018	4	0.25	0.02	3	0	23	30	20+	20+
93	0.00018	4	0.12	0.01	3	0	20+++	---	---	20+++
94	0.00018	16	0.50	0.41	4	0	20+	20+	20+	20+

TABLE 82. SMALL-SCALE COALESCER TEST RESULTS (Cont'd)

Homogenizer pressure: 70 to 90 psi
Water injection rate: 0.1%

Test cell inlet pressure: 70 psi
Test cell inlet temperature: 66° to 78°F

Test no.	Fiber diameter, in.	Compressed density, lb/ft^3	Thickness, in.	Coalescer cell ΔP, psi		Pre-test	AEL rating‡ in mg/ℓ at indicated time (min)			
				Air flow*	Fuel flow†		5	10	15	20
95	0.00018	16	0.12	0.08	3	0	2	2	4	4
96	0.00018	16	0.25	0.21	3	0	20+++	---	---	20++
97	0.00018	16	0.50	0.49	3	0	20+++	20+++	---	20++
98	0.00018	16	0.25	0.22	4	0	7	9	10	9
99	0.00018	16	0.12	0.09	3	0	20++	20+++	20+++	20+++
100-103	See Table 84									
104	0.00011	4	0.50	0.13	3	0	1	2	4	4
105	0.00011	4	0.12	0.03	3	0	20+++	---	---	20+++
106	0.00011	4	0.25	0.06	3	0	27	31	20+++	20+++
107	0.00011	4	0.12	0.03	3	0	29	20+++	---	20+++
108	0.00011	4	0.50	0.15	3	0	2	5	5	4
109	0.00011	4	0.25	0.06	3	0	20+++	20+++	20+++	20++
110	0.00011	8	0.25	0.18	3	0	20++	20+++	20+++	20++
111	0.00011	8	0.50	0.32	4	0	4	20++	20+++	---
112	0.00011	8	0.12	0.07	3	0	20+++	20+++	20+++	20++
113	0.00011	8	0.50	0.36	5	0	20+	20+	20+	20+
114	0.00011	8	0.25	0.16	3	0	4	12	---	12
115	0.00011	8	0.12	0.08	4	0	4	13	27	20
116	0.00011	16	0.50	0.97	5	0	0	0	1	2
117	0.00011	16	0.25	0.50	5	0	1	1	3	2
118	0.00011	16	0.12	0.19	4	0	5	5	5	6
119	0.00011	16	0.12	0.12	4	0	2	3	4	5
120	0.00011	16	0.50	0.97	5	0	20+	20+	20++	20+++
121	0.00011	16	0.25	0.46	4	0	1	3	3	3
122	0.00003	4	0.12	0.50	5	0	20+++	---	---	---
123	0.00003	4	0.50	1.97	8	0	20+++	---	---	---
124	0.00003	4	0.25	1.20	7	0	20+++	---	20+++	20++
125	0.00003	4	0.12	0.46	4	0	20+++	20+++	---	---
126	0.00003	4	0.25	1.20	4	0	20+++	---	---	---
127	0.00003	4	0.50	2.16	9	0	20+++	---	---	--

*Measured at 8 ℓ/min airflow
†Measured in small-scale coalescer before start of water injection
‡Corrected for sample volume except for 20+, 20++, and 20+++ values

TABLE 83. AVERAGE AEL RATINGS FOR MEDIA FIBER DIAMETER-DENSITY-THICKNESS COMBINATIONS

Compressed density, lb/ft³	Fiber dia, in.	Average AEL rating (mg/ℓ) at indicated thickness 1/8 in.	1/4 in.	1/2 in.
4	0.00003	150	131	150
	0.00011	126	120	3
	0.00018	150	81	37
8	0.00003	23	53	98
	0.00011	83	79	58
	0.00018	119	11	18
16	0.00003	16	22	150
	0.00011	4	2	40
	0.00018	59	27	59

Overall averages by classes

Fiber diameter:	0.00003	264
	0.00011	172
	0.00018	187
Density:	4	316
	8	181
	16	126
Thickness:	1/8	243
	1/4	175
	1/2	204

TABLE 84. SMALL-SCALE COALESCER TEST RESULTS, MULTILAYER MEDIA

Homogenizer pressure: 72 to 78 psi
Water injection rate: 0.1[illegible]

Test cell inlet pressure: 70 psi
Test cell inlet temperature: 66° to 68°F

Test no	First media layer: Compressed density lb/ft³	First media layer: Thickness, in	Second media layer*: Spacer, in.	Second media layer*: Compressed density lb/ft³	Second media layer*: Thickness, in.	Coalescer cell ΔP, psi: Air-flow†	Coalescer cell ΔP, psi: Fuel flow‡	AEL rating** in mg/ℓ indicated time (min): Pre-test	5	10	15	20
100	16	0.25	0	4	0.25	0.19	3	0	2	4	4	4
101	16	0.25	0	4	0.25	0.25	3	0	2	4	4	4
102	16	0.25	0.3[illegible]	4	0.25	[illegible]	3	0	1	1	1	2
103	16	0.25	0.38	4	0.25	[illegible]	3	0	10	27	13	19

*Media fiber diameter: 0.00018 in.
†Measured at [illegible] airflow. Pressure drop across both media layers.
‡Measured in small-scale coalescer before start of water injection.
**[illegible]ected for sample volume.

TABLE 85. SMALL-SCALE COALESCER TESTS RESULTS–HELIUM DRIVE

Helium pressure: 80 psi on fuel
Orifice diameter: 0.016 in.
Water injection rate: 0.1%

Test cell inlet pressure: 20 to 40 psi
Test cell inlet temperature: 66°F to 74°F

Test no.	Fiber diameter, in.	Compressed density lb/ft^3	Thickness, in.	Coalescer cell ΔP, psi: Air flow*	Coalescer cell ΔP, psi: Fuel flow†	Pre-test	AEL rating‡ in mg/ℓ at indicated time (min): 5	10	15	20
50	0.00003	8	0.50	4.40	18	0	20+++	20+++	20+++	20+++
51	0.00003	8	0.25	3.90	15	0	5	21	20++	20++
52	0.00003	8	0.12	1.85	11	0	1	28	28	20++
53	0.00003	8	0.25	3.47	15	0	13	---	---	---
54	0.00003	8	0.50	4.86	17	0	20+++	20+++	20+++	20+++
55	0.00003	8	0.12	1.93	10	0	20+++	20+++	20+++	20+++
56	0.00003	8	0.50	---	14	0	20+++	20+++	20+++	20+++
57	0.00003	8	0.25	---	11	0	20+++	20+++	20+++	20+++

*Measured at 8 ℓ/min airflow.
†Measured in small-scale coalescer before start of water injection.
‡Corrected for sample volume except for 20+, 20++, and 20+++ values.

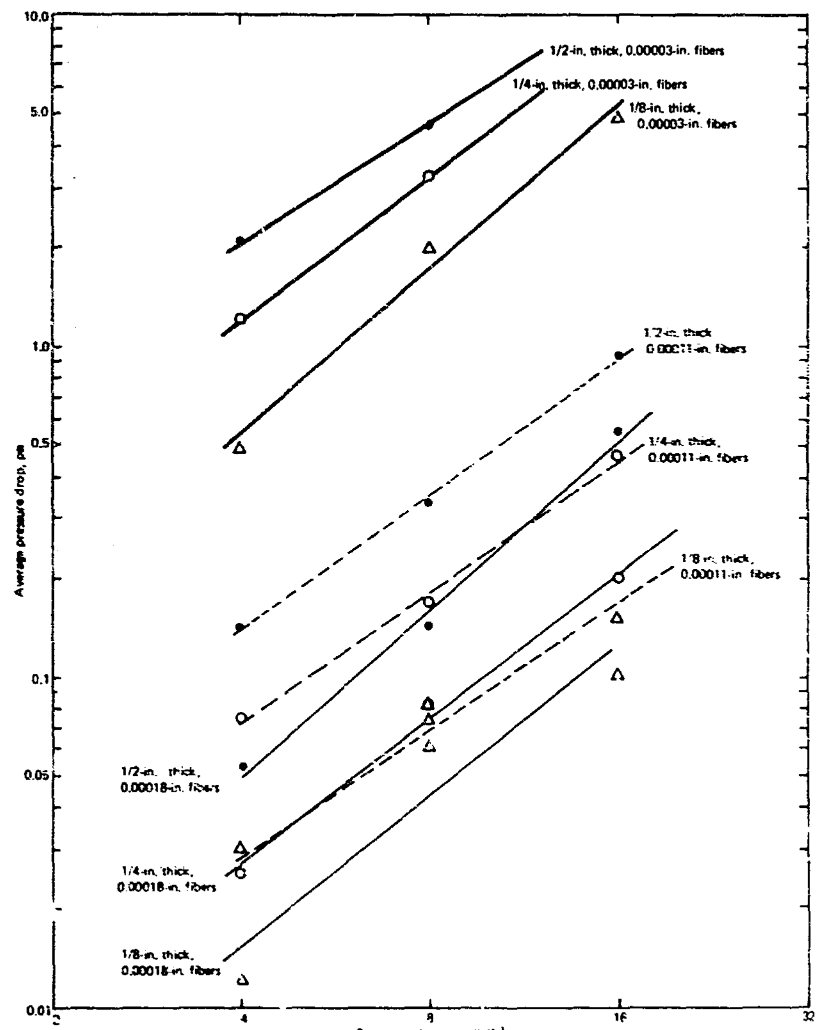

FIGURE 12. AVERAGE AIRFLOW PRESSURE DROP OF COALESCENCE MEDIA VS MEDIA DENSITY

The differential pressure of the coalescer cell was also measured when fuel was flowing during the coalescence tests. The differential pressure measured just before the start of water injection, reported in Tables 82 and 85, would also be expected to vary regularly with media density and thickness. The test data for 0.00003-in.-dia fiber media show such a relation (see Figure 13). In the case of the coarser fibers (0.00011-in. and 0.00018-in. dia), the range of fuel-flow differential pressure was too limited to demonstrate clear-cut relationships between pressure and media thickness and density. Definite relations between these variables no doubt exist, but the differential pressure data were not sufficiently accurate nor precise to reveal these.

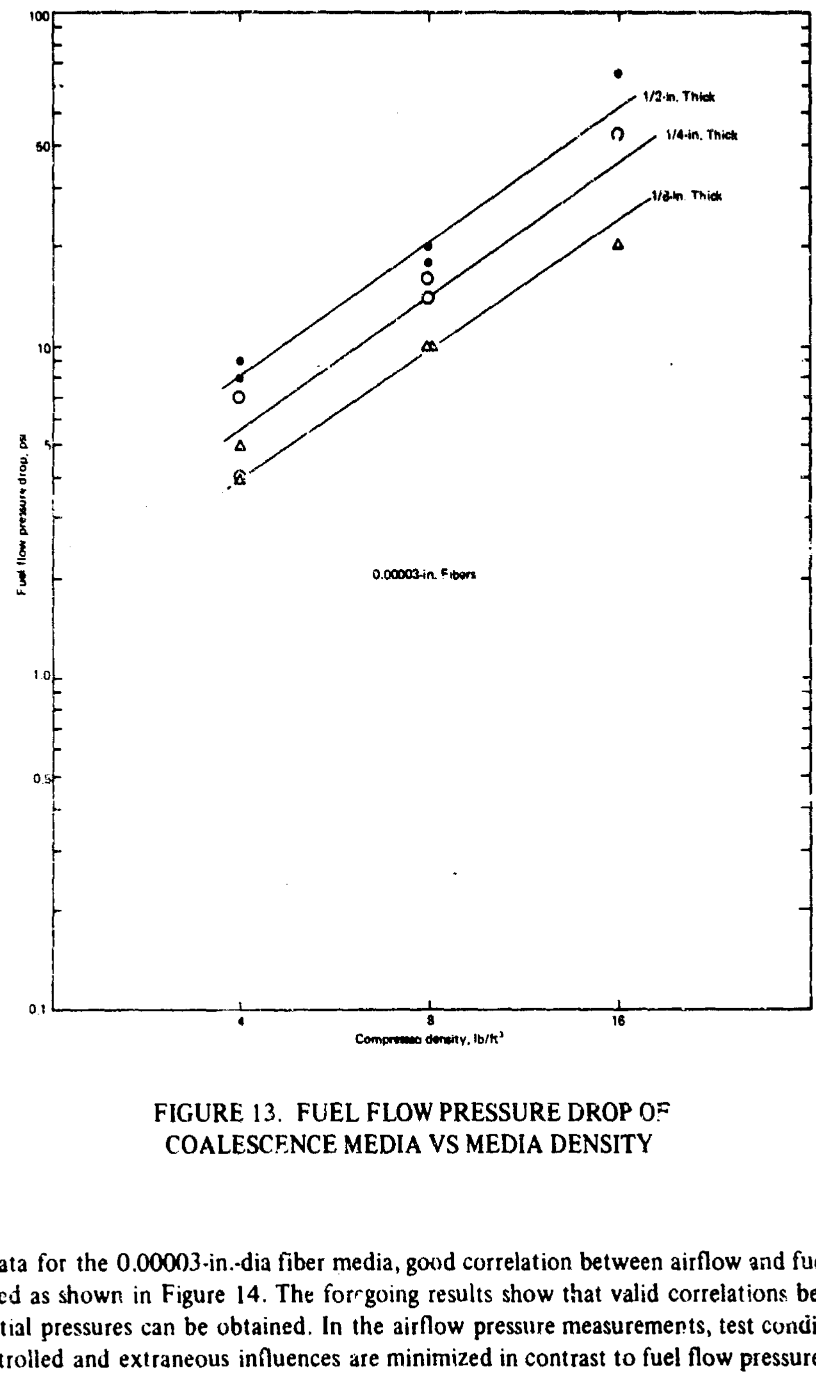

FIGURE 13. FUEL FLOW PRESSURE DROP OF COALESCENCE MEDIA VS MEDIA DENSITY

Using the data for the 0.00003-in.-dia fiber media, good correlation between airflow and fuel flow differential pressure is obtained as shown in Figure 14. The foregoing results show that valid correlations between airflow and fuel flow differential pressures can be obtained. In the airflow pressure measurements, test conditions can be easily and precisely controlled and extraneous influences are minimized in contrast to fuel flow pressure measurements. It is suggested that in future coalescence studies, media flow resistance be characterized on the basis of airflow measurement, perhaps in conjunction with differential pressure measurements taken during the coalescence tests.

4. Conclusions and Recommendations

On the basis of test results, the best of nine combinations of parameters for conventional glass-fiber media (fiber diameter, density, and thickness) in removing dispersed free water from fuel was 0.00011-in.-dia fiber, 16-lb/ft^3 density, and 1/4-in. thickness.

Results from a limited number of tests on two-layer media suggest that a combination of dense and less dense media (in the direction of fuel flow) can provide good coalescence. This is in accord with common design practice.

The results indicate that the test methods could distinguish between the coalescence performance of several glass-fiber media. Continuation of this work should provide further information about the effects of the media parameters and the effectiveness of media other than that made of glass-fibers. One very important aspect of the coalescence studies which was not attempted in this program, but which warrants attention, is the correlation between small-scale coalescer tests results and filter-separator test results.

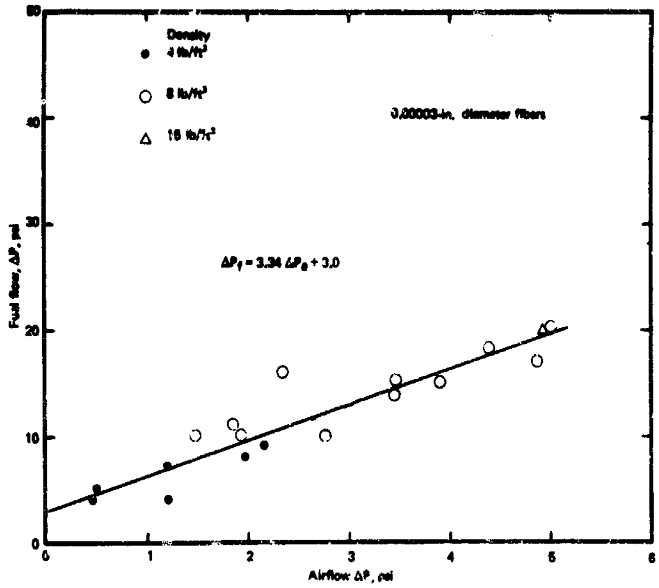

FIGURE 14. CORRELATION BETWEEN FUEL FLOW ΔP AND AIR FLOW ΔP

It is recommended that improved uniformity in test conditions would result from a design using either an outside-pressurized bladder or a large-displacement, one-stroke piston to drive the test fuel, in conjunction with either an orifice, a mechanical disperser, or an ultrasonic disperser. Such a system would avoid gas-bubbling problems associated with gas-drive systems, as well as the pump wear debris and pulsating-flow problems associated with pump-drive systems.

SECTION VIII

MISCELLANEOUS

1. Media Plugging at Low Temperatures

a. Introduction

The phenomenon of accelerated element plugging under low-temperature field conditions was the subject of this study. Analysis of elements which had exhibited premature plugging under such field conditions had revealed nothing unusual except high contents of glycerol, and the problem had been tentatively attributed to trace amounts of insoluble glycerol in fuel-FSII blends. At the nominal use concentration of 0.1 vol % FSII in the fuel, the total glycerol content of the fuel is 0.0004% (4 ppm) when using the FSII that was standard at the time this work was performed*. It has been stated that the content of insoluble glycerol in such fuel blends is about 1 ppm; however, this can be only a rough approximation, since the glycerol solubility must be influenced very markedly by the water content of the fuel, as well as by fuel aromaticity and temperature.

Preliminary efforts to design an apparatus which could closely duplicate actual field conditions on a small scale centered on a pump-drive system using a small gear pump of the same type as those used in separometer and fuel coker equipment. This system proved completely impractical, since the quantities of solid material in the fuel passing through the media were so great as to invalidate any plugging results. The material was almost certainly pump wear debris. The system was then rebuilt using helium drive.

b. Apparatus

A stainless steel fuel tank was pressurized to 70 psi with helium to drive the fuel through the rig. All tubing used was stainless steel, except the cooling coil, which was aluminum†. By proper choice of flow plan and physical arrangement of components, gas-bubbling problems were avoided. The flow plan of the apparatus is shown in Figure 15. Designed in this way, the rig operated very smoothly, and the data can be accepted with confidence as representative of the actual behavior of the fluids rather than vagaries of the test system.

The test cell used was similar to that of the ASTM water separometer. Inside diameter of the cell was 0.75 in. and depth was 0.50 inch. Spacers (orifice disks) were used to reduce the compression gap to 0.072 inch. The

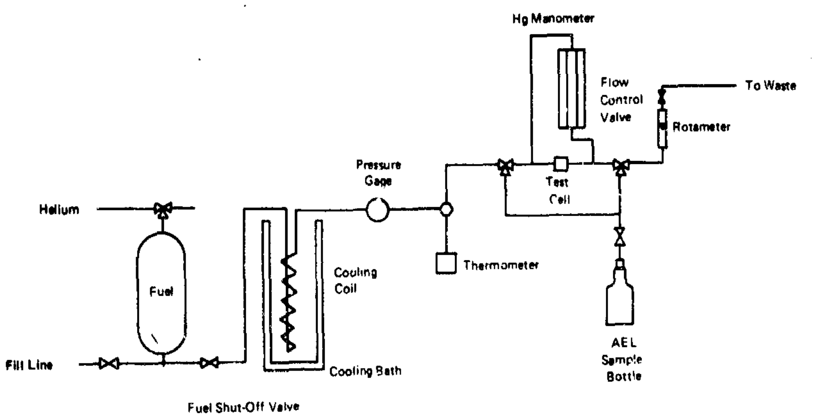

FIGURE 15 SMALL-SCALE MEDIA PLUGGING APPARATUS

*The FSII used in this work conformed to MIL-I-27686D and contained 0.4% glycerol and 99.6% ethylene glycol monomethyl ether (EGME).

†Copper tubing, used in early work, appeared to contribute contaminants to the fuel under some conditions.

orifices in the spacers and in the cell itself were 0.18 to 0.19 in. in diameter. The spacer used immediately upstream of the media had an orifice diameter of 0.19 in., and this is the value used in calculating flow area, velocity, and throughput ratio.

The test cell was located within about 2 ft of the cooling coil outlet (see Figure 15) to minimize heat pickup in the line, and all cold lines and the cell itself were heavily insulated. At the normal operating conditions of 100 ml/min, holding the cell-inlet fuel temperature at 35°F, a cooling bath temperature of about 18°F was required.

For the work reported here, each set of test media consisted of a fine and coarse separometer disk, cut down to 0.75 in. in diameter. These were installed in the cell so that the fuel flowed first through the fine and then the coarse disk. The cut-down disks were weighed and checked individually for airflow resistance in the same cell used for the test, with an airflow rate of 8 ℓ/min.

c. **Program and Procedure**

This program was started using ASTM reference-grade iso-octane as the base fuel, in order to avoid possible complications with fuel aging and gum precipitation during the test series. Not enough iso-octane to complete the program could be obtained on a timely basis, so the major portion of the program was run with uninhibited JP-4 base fuel. This was blended with FSII (0.4% glycerol) or with EGME (glycerol-free FSII) in concentrations of 0.15 or 0.25%.

Each test was run on 36 ℓ of fuel, filtered through a 0.8μ membrane filter, and blended with FSII or EGME according to closely controlled procedures that are outlined below. In the following summary of the test series, all tests (unless otherwise indicated) were run on JP-4 fuel at a cell inlet temperature of 35°F, with a time lapse of not more than 2 hr between final filtration of the fuel and the start of the pumping test.

Run no.	FSII, vol %	Procedure and blend container	Remarks
1-4	0	A. Tank	Iso-octane base fuel in Runs 1-2
5-6	0.25	B. Unlined cans	
7-11	0.15	B. Unlined cans	Temperature 77°F in Run 9 EGME additive in Runs 10-11
12-13	0	B. Unlined cans	18 hr in can (Run 12) 2 hr in can (Run 13)
14	0	A. Tank	
15	0	B. Lined cans	
16-18	0.15	C. Tank	EGME additive in Run 18

In Procedure A, the fuel was prefiltered through a membrane filter installed in the fill line of the fuel tank of the apparatus (see Figure 16), evacuating the fuel tank to draw the fuel through the filter. This filtered fuel was then used in the test without further handling. No FSII or EGME was involved in any of the fuels handled by Procedure A. The time lapse between filtration and start of pumping test was very short.

In Procedure B, base fuel was prefiltered into cleaned cans, blended with FSII or EGME, if applicable, and then drawn directly into the fuel tank without further filtration. This procedure was intended to bring into the test system any insoluble material precipitated from the fuel by the addition of FSII or EGME. However, any insoluble material that settled out in the blend cans would not be brought into the test. Storage time in the cans was less than 2 hr except in two special tests where it was stored for 2 and 18 hr. If no additive blending was involved, as in Run 15, the time lapse (storage time) was very short.

In Procedure C, prefiltered base fuel was drawn into the fuel tank, line-blending the additive by injecting at a rate to approximately match the final additive concentration (see Figure 17). This method minimized the probability of losing insoluble matter before it reached the test filter during the pumping test. The time lapse between filtration and start of the pumping test was very short.

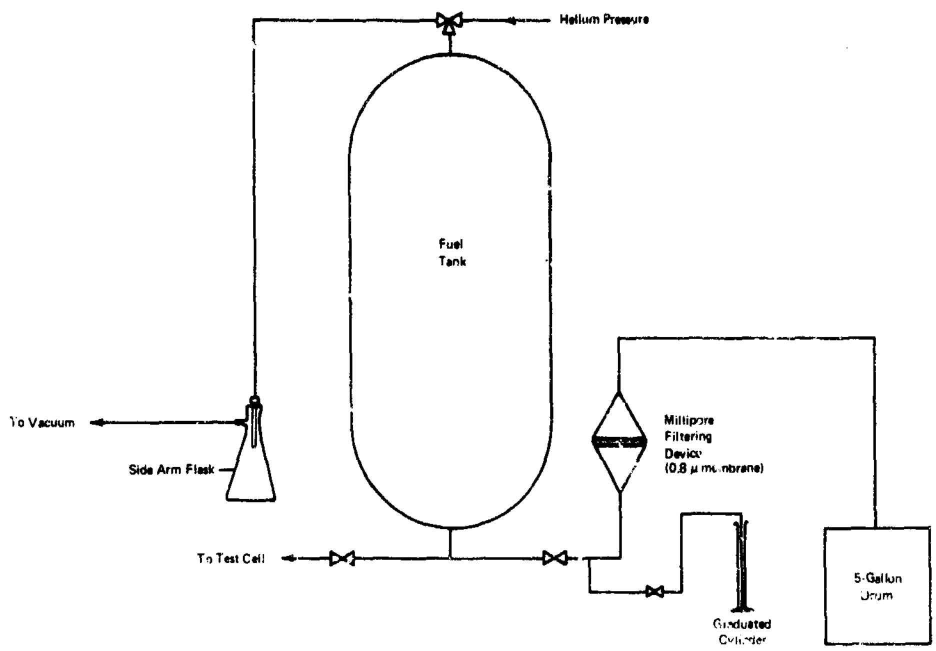

FIGURE 16. FUEL TANK CHARGING APPARATUS
AS USED FOR MEDIA PLUGGING IN
TESTS 1-4 AND 14

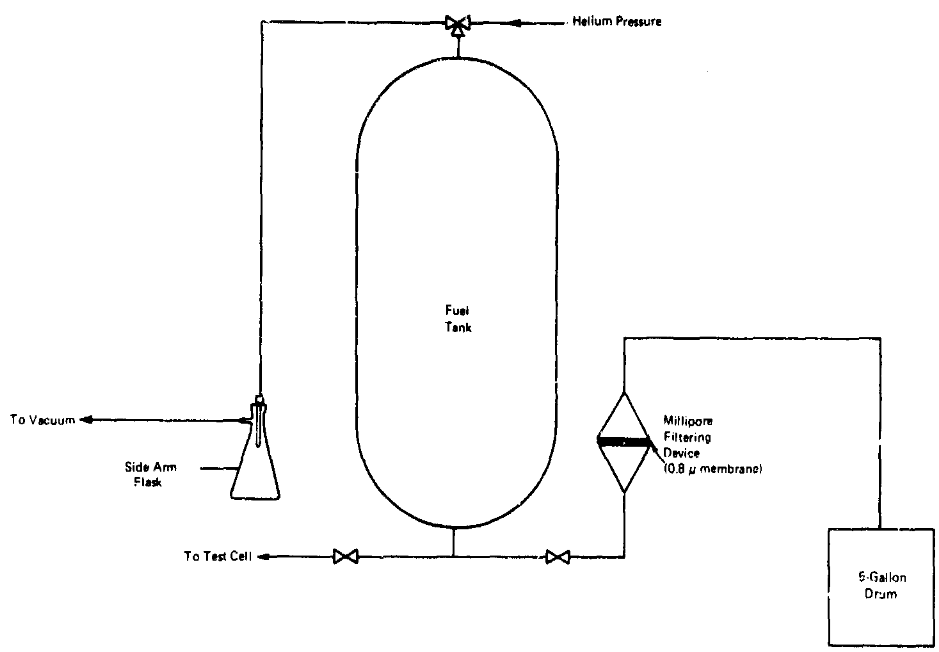

FIGURE 17. FUEL TANK CHARGING APPARATUS
AS USED FOR MEDIA PLUGGING IN
TESTS 16-18

All blending and charging operations were conducted at normal laboratory temperature. No attempt was made to control the dissolved water content of the base fuel. All equipment and blending containers were cleaned thoroughly to remove extraneous solid contaminants.

When starting a test, flow was directed through the bypass line until conditions were stabilized, then switched through the test cell. Zero time was selected as the time at which pressure rise became more moderate following the very rapid pressure rise accompanying the start of flow through the cell. Assigning the zero time was quite difficult in tests that gave rapid plugging.

In most cases, ΔP readings and system conditions were recorded every 10 min after the start of the test. The fuel flow rate was maintained at 100 ml/min for 251.75 min. In some tests performed at low temperature, flow was continued after 251.75 minutes, and the cooling bath was removed until the fuel temperature came to equilibrium with ambient. A post-test manometer reading was recorded when the decreasing ΔP stabilized.

d. Throughput Calculations

A throughput of 100 ml/min for 251.75 min (25.175 ℓ) corresponds to a throughput ratio of 235 gal/in² of filter surface, using the 0.19-in. orifice diameter to define the filter surface area. On this same basis, the superficial flow velocity is 17.93 ft/min. For a military-standard element processing 50,000 gal of fuel at 20 gpm, the throughput ratio is 238 gal/in² and the superficial flow velocity is 1.84 ft/min.* Thus, it can be seen that the experiment matches the field conditions closely on the basis of throughput ratio, but the flow velocity in the small rig is approximately 10 times that of the full-size element. The higher flow velocity was chosen in the program in order to bring the test period within reasonable limits. It should be noted that the calculated velocity of 17.93 ft/min in the cell, based on the 0.19-in. orifice diameter, is not really representative of the true conditions in the cell, since the fuel stream undoubtedly spreads out through a greater area of the bed. Based on measurements of media stain diameters, it appears that the true superficial velocity in the cell must be somewhat under 25% of the nominal 17.93 ft/min; i.e., somewhat under 4.5 ft/min. A comparison of calculated velocities and throughputs is given in the following table:

	Superficial velocity, ft/min	Throughput, gal/in²
Mil-std element, 50,000 gal	1.84	238
Small-scale apparatus:		
Based on 0.19-in. orifice	17.93	235
Based on estimated flow area	<4.5	<60

e. Test Results and Discussion

Data obtained in all 18 runs on the gas-drive plugging rig are summarized in Table 86, and the pressure-drop data are plotted in Figures 18 to 23. Fluids without FSII or EGME tested immediately after filtering (runs 1-4, 14 and 15) gave practically no plugging (Figure 18). In contrast, Runs 12 and 13, performed with uninhibited JP-4 that had been filtered into and stored in unlined steel cans, gave moderate media plugging. A plot of the values obtained, shown on Figure 19, indicates that the pressure-drop increase was almost linear throughout the tests. This is in marked contrast to plugging rates obtained with FSII-blended fuels, where the pressure-drop increase rate tended to diminish with test time. The behavior of the fuel in Tests 12 and 13 suggests the possibility of foreign contamination or of time-dependent changes in the fuel (such as aggregation of colloidal gum particles) or chemical reactions of the fuel with the container.

For the tests on JP-4 with FSII (Tests 5-9, 16, and 17), the data, as shown in Figures 20, 21, and 22, define generally smooth curves, except that very definite changes in slope, i.e., changes in plugging rate, are evident

*The values of throughput ratio and velocity for the military-standard element were calculated on the basis of a flow area of 1353 cm² (209.7 in²), which is the average outside surface area of eight elements that were measured. The throughput of 50,000 gal per element corresponds to 1,500,000 gal through a 600-gpm filter-separator

TABLE 86. MEDIA PLUGGING TEST SUMMARY

Run no.	1	2	3	4	5	6	7	8	9
Base fluid	Iso-octane	Iso-octane	JP-4	JP-4	JP-4	JP-4	JP-4	JP-4	JP-4
Additive	None	None	None	None	FSII	FSII	FSII	FSII	FSII
Concn. of additive, %	0	0	0	0	0.25	0.25	0.15	0.15	0.15
Vessel used to blend test fluid	Tank	Tank	Tank	Tank	Unlined cans	Unlined cans	Unlined cans	Unlined cans	Unlined cans
Test fluid storage time (after filtering), hr	---	---	---	---	---	---	---	---	---
Test temperature, °F	35	35	35	35	35	35	35	35	77
*Disk properties**									
Coarse disk weight, mg	51	52	50	50	56	49	53	46	50
Fine disk weight, mg	27	27	28	29	26	32	27	28	28
Mean compressed density, lb/ft^3	9.4	9.5	9.4	9.5	9.8	9.7	9.6	8.9	9.4
Airflow ΔP, in. Hg, coarse	0.53	0.57	0.59	0.56	0.50	0.50	0.43	0.43	0.53
fine	2.16	2.20	2.52	2.50	2.44	2.47	2.69	2.63	2.18
Test results(†)									
Cell ΔP in. Hg, initial	1.73	2.14	2.95	2.78	4.05	4.15	4.30	3.32	2.39
final	1.88	2.34	3.11	2.88	16.26	10.84	13.03	9.69	4.63
increase	0.15	0.20	0.16	0.10	12.21	6.69	8.73	6.37	2.24
after warmup	---	---	2.60	2.38	8.55	---	---	---	(4.63)
AEL free water in bypass fuel at end of test, mg/ℓ	‡	0	0-1	0	0-1	0-1	0-1	0	0
Disk stain color rating	Trace	Trace	None	None	Dark	Medium	Light	Medium	Slight
Disk stain diameter, in.	---	---	---	---	3/8	3/8	3/8	3/8	3/8

*Standard separometer disks cut down to 3/4 in. diameter. Cell compression gap 0.072 in., orifice diameter 0.190 inch. Airflow checks run with single disk (coarse or fine) in this cell, airflow 8 ℓ/min.
†Gas drive, 70 psig helium pressure. Fuel flow rate 100 ml/min, test duration 251.75 min. Based on orifice area, linear velocity is 17.93 ft/min, and throughput ratio is 234.6 gal/inch^2. Pressure drops are direct manometer readings, not corrected for fuel leg.
‡Free water indicated, but pattern too irregular to rate quantitatively.

TABLE 86. MEDIA PLUGGING TEST SUMMARY (Cont'd)

Run no	10	11	12	13	14	15	16	17	18
Base fluid	JP-4	JP-4	JP-4	JP-4	JP-4	JP-4	JP-4	JP-4	JP-4
Additive	EGME	EGME	None	None	None	None	FSII	FSII	EGME
Concn. of additive, %	0.15	0.15	0	0	0	0	0.15	0.15	0.15
Vessel used to blend test fluid	Unlined cans	Unlined cans	Unlined cans	Unlined cans	Tank	Epoxy-lined cans	Tank	Tank	Tank
Test fluid storage time (after filtering), hr	---	---	18	2	---	---	---	---	---
Test temperature, °F	35	35	35	35	35	35	35	35	35
*Disk properties**									
Coarse disk weight, mg	43	44	56	53	53	43	44	45	40
Fine disk weight, mg	27	31	26	33	30	28	28	28	29
Mean compressed density, lb/ft^3	8.4	9.0	9.9	10.3	10.0	8.5	8.7	8.8	8.3
Airflow ΔP, in. Hg, coarse	0.51	0.48	0.49	0.49	0.47	0.41	0.41	0.40	0.39
fine	2.25	2.31	2.34	2.37	2.60	3.01	2.99	2.97	2.97
Test results(†)									
Cell ΔP, in. Hg, initial	4.31	3.33	3.18	3.45	2.59	3.03	5.20	3.10	2.69
final	11.35	8.19	8.75	8.35	2.79	3.50	11.17	9.35	3.11
increase	7.04	4.86	5.57	4.90	0.20	0.47	5.97	6.25	1.96
after warmup	---	4.25	3.49	3.31	2.19	2.70	4.15	---	2.30
AEL free water in bypass fuel at end of test, mg/ℓ	4-5	0	0	0	0	0-1	0-1	2-3	0
Disk stain color rating	Dark	Light	Trace	Light	None	Light	Light	Medium	Light
Disk stain diameter, in.	3/8	3/8	3/8	3/8	---	3/8	7/16	5/16	3/8

*Standard separometer disks cut down to 3/4 in. diameter. Cell compression gap 0.072 in., orifice diameter 0.190 inch. Airflow checks run with single disk (coarse or fine) in this cell, airflow 8 ℓ/min.
†Gas drive, 70 psig helium pressure. Fuel flow rate 100 ml/min, test duration 251.75 min. Based on orifice area, linear velocity is 17.93 ft/min, and throughput ratio is 234.6 gal/inch^2. Pressure drops are direct manometer readings, not corrected for fuel leg.

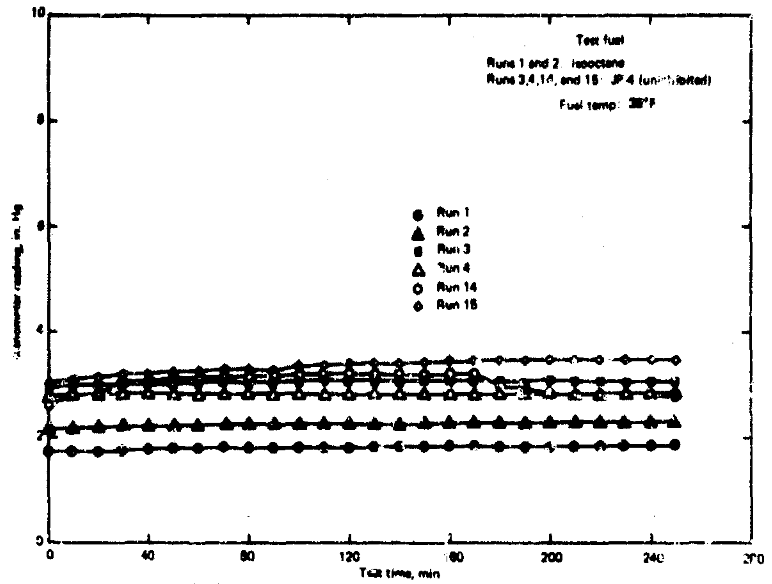

FIGURE 18. MEDIA PLUGGING TESTS ON UNINHIBITED FUELS AT 35°F

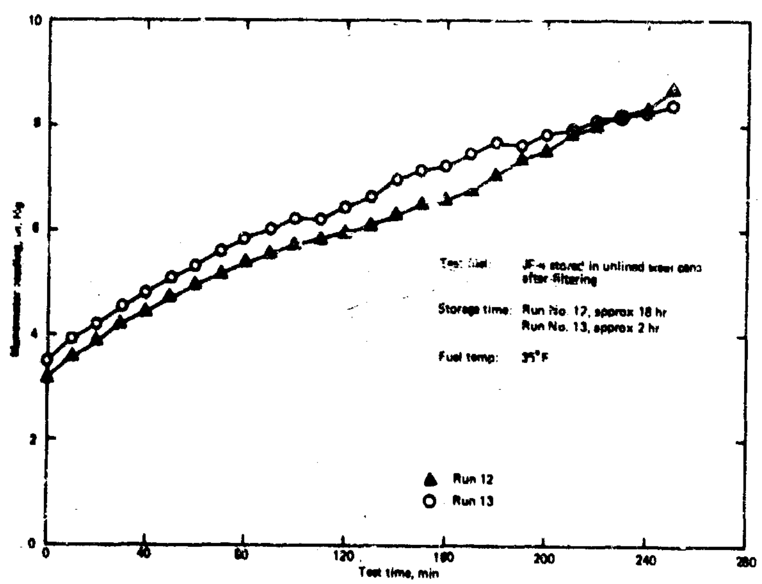

FIGURE 19. MEDIA PLUGGING TESTS ON STORED, UNINHIBITED JP-4 AT 35°F

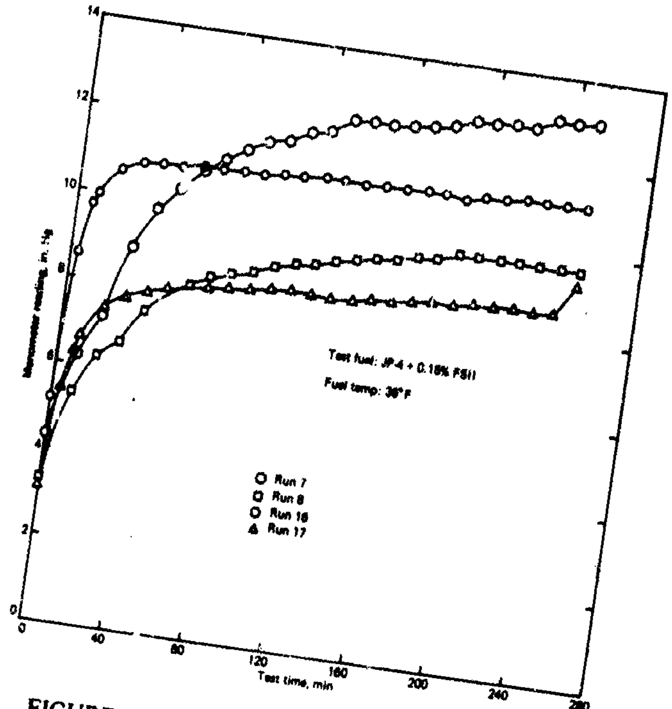

FIGURE 21. MEDIA PLUGGING TESTS ON
JP-4 + 0.15% FSII AT 35°F

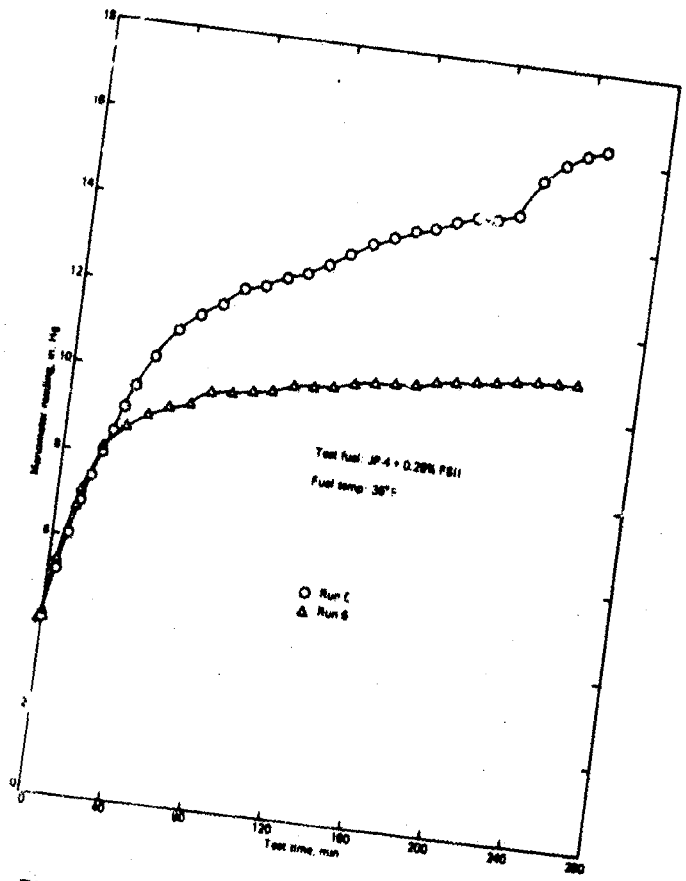

FIGURE 20. MEDIA PLUGGING TESTS ON
JP-4 + 0.25% FSII AT 35°F

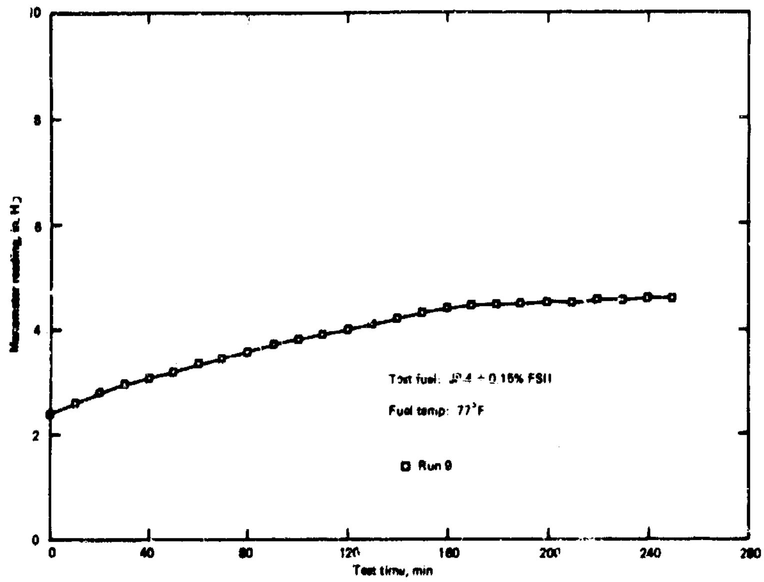

FIGURE 22. MEDIA PLUGGING TEST ON JP-4 + 0.15% FSII AT ROOM TEMPERATURE

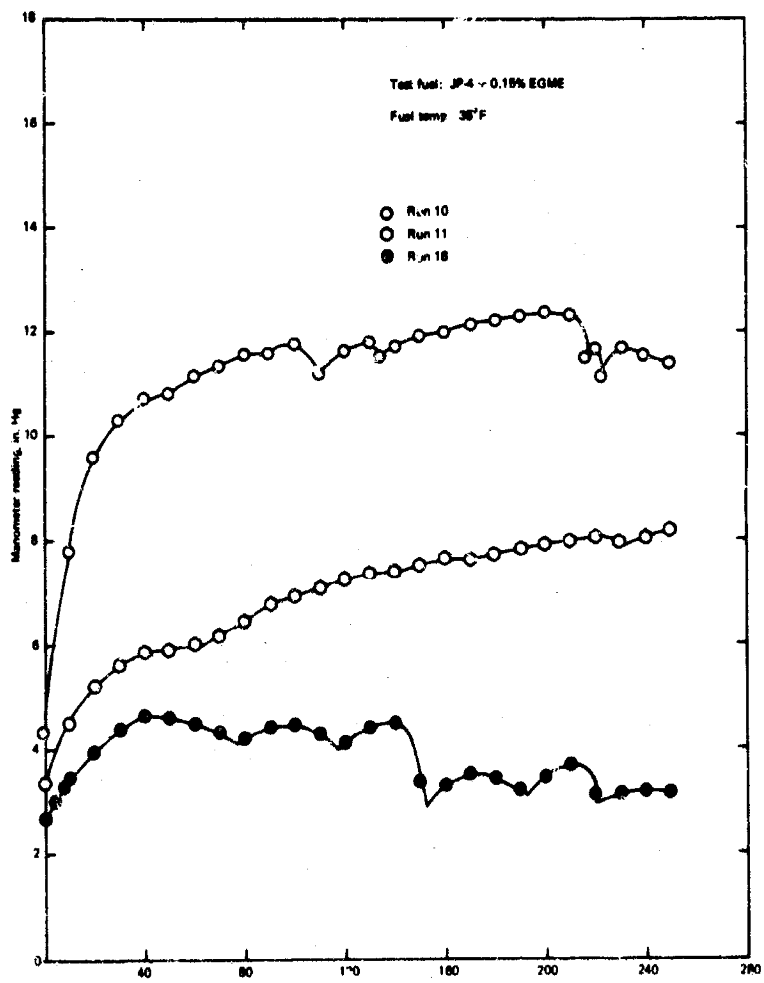

FIGURE 23. MEDIA PLUGGING TESTS ON JP-4 + 0.15% ETHYLENE GLYCOL MONOMETHYL ETHER AT 35°F

at certain times. These changes would manifest themselves when a plugging rate that had previously been well stabilized would suddenly increase with no change in system conditions. Subsequently, the plugging rate would gradually stabilize and again follow a smooth curve, until the next "jump." All of the curves for runs on fluids containing FSII showed instances of the same sort of behavior. However, in the single run at room temperature (Figure 22), there was less plugging and the "jumps" were not very evident.

All curves for tests on fuel-FSII blends were concave downward, that is, the plugging rate tended to diminish as the test progressed. The superimposed "jumps" did not change this overall trend.

Runs 10, 11, and 18 (see Figure 23), performed on fuel-EGME blends, gave rather erratic data. Media plugging in these three tests ranged from light to heavy, and plots of values obtained were somewhat like those obtained with fuel FSII-blends. The phenomenon of breaks in the plugging rate was much more evident with the fuel-EGME blends, and in two tests was quite severe. Although nonconclusive, the findings of these tests do suggest strongly that glycerol is not the sole cause of premature element failure at low temperatures.

The general trend of the plugging curves obtained with fuel-FSII and fuel-EGME blends. i.e., concave downward, is evidence that this plugging represents a buildup toward an equilibrium condition. Assuming that some insoluble liquid constituent of the test fluid is sticking on the fibers of the media, the first effect will be a rapid increase in pressure drop as the passages available for hydrocarbon flow become restricted because of an effective enlargement of the fibers. When the liquid coating of the fibers has built up to a certain equilibrium thickness, this liquid will tend to migrate through the bed and will attain an equilibrium condition in which the amount of insoluble liquid leaving the bed (per unit time) is the same as the amount entering. This interpretation accounts for the concave-downward shape of the curves and the general trend toward leveling out. Graphical analysis of the curves has indicated that they are hyperbolic, approaching asymptotically some limiting pressure drop. This behavior is in marked contrast to that observed when media are being plugged by loading with solids at a constant rate; there the typical curves are concave upward and generally represent exponential curves of the form $P - P_o = Ae^{kt}$. Such plugging with solids represents a cumulative effect so long as no significant amounts of solids pass on through the bed. If significant amounts of solids do pass through the bed, the resultant plot will be expected to be somewhere between a hyperbolic and an exponential curve. This reasoning leads to a possible explanation for the behavior observed in Tests 12 and 13. In these tests, fuel which had no FSII or EGME had been stored, in one case for 2 hr and in the other for 18 hr, in unlined metal cans prior to testing. The possibility of fuel contamination by solid material during this storage is suggested by the shape of the plots obtained (see Figure 19).

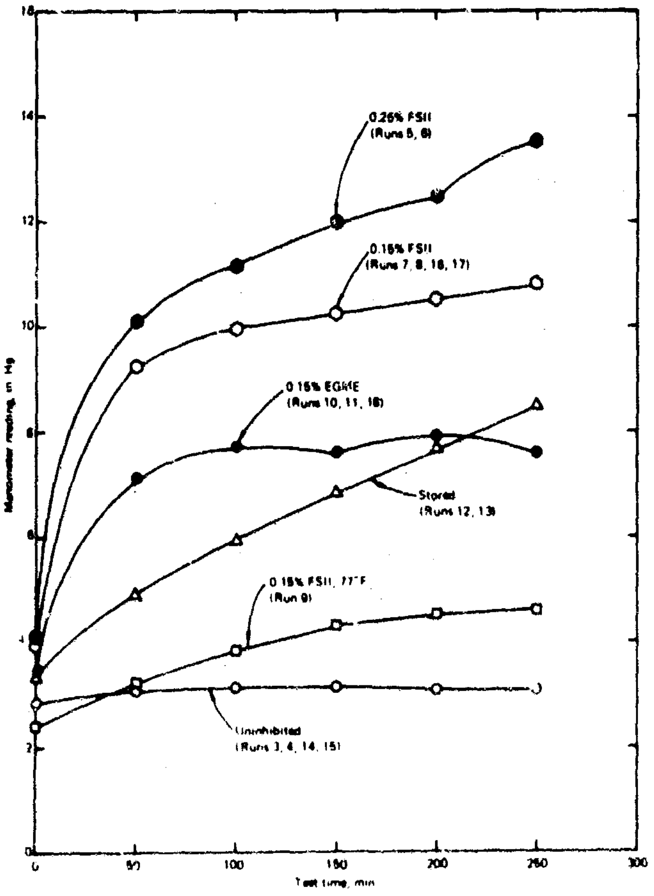

FIGURE 24. AVERAGE VALUES OBTAINED UNDER VARIOUS PLUGGING TEST CONDITIONS

Figure 24 represents the plots of the average of all the data available for each different test condition. It clearly shows the different behavior of each of the test fluids with respect to media plugging rate at low temperature and the behavior of one test fluid at room temperature.

In plugging of media by liquid or semi-liquid material, the curves obtained would be

perfectly smooth and hyperbolic if the fluid entering the bed were of constant composition with respect to content of insoluble liquid. This situation would exist if the insoluble liquid or semiliquid material were dispersed uniformly in the fluid in extremely small, possibly submicroscopic droplets. However, once a "slug" of the insoluble liquid hits the bed, the behavior must change. This slug may be (and probably is) still a very small droplet, but large in relation to the amount of insoluble liquid retained on a fiber. When such a slug hits the bed, the pressure drop will jump, but will again tend to level off and may even decrease as the excess insoluble liquid works through and out of the bed. This interpretation is consistent with the segmented nature of the curves obtained with FSII and EGME blends.

What we are seeing in the data plots are probably the effects of only the larger droplets of insoluble liquid. Smaller droplets might have the same effect, but could not be detected.

It will be noted from the data plots and from Table 86 that the additive-free fluids which were not stored in unlined metal cans gave pressure-drop increases of only 0.10-0.62 in. Hg. The JP-4 with FSII gave pressure-drop increases of 6 to 12 in. Hg in the low-temperature tests and about 2 in. Hg in the room-temperature test. There was only a slight difference between the 0.15 and 0.25% levels of FSII content, the former giving 6- to 9-in. Hg buildup and the latter 7- to 12-in. Hg. This lack of any significant effect of FSII concentration is in accord with the theory of equilibrium buildup of an insoluble liquid or semiliquid in the bed.

In 10 of the tests (Runs 3 to 5, 11 to 16, and 18), flow was continued through the cell after the test had been completed and the cooling bath had been removed, so as to obtain manometer readings after warmup. These are listed in Table 87, along with calculated values of pressure drop at 77°F before and after test. The calculated values are obtained by multiplying the respective 35°F readings by the viscosity ratio (cs_{77}/cs_{35} = 1.01/1.40). In the case of the initial values, the calculated pressure drops are the only 77°F values available, since flow through the cell was started with chilled fluid. The calculated initial 77°F values are subject to the same error as the actual 35°F readings from which they are calculated, i.e., error introduced by ambiguity in defining the "zero-time" reading in many of the tests. In the case of the values obtained after warmup, the pressure drops calculated for 77°F may be compared with the actual readings obtained after warmup to 69 to 75°F and with the calculated initial 77°F values, thus obtaining a measure of the type of plugging. Here we may define "permanent" plugging as that remaining after warmup, and "temporary" plugging as that which disappears. Physically, permanent plugging should be caused by solid, high-melting particles or by equilibrium buildup of liquid materials; temporary plugging may be caused by solids that melt during warmup, or by liquid materials that tend to dissolve or wash out by entrainment when the bed is warmed.

TABLE 87. ΔP READINGS AFTER WARMUP IN MEDIA PLUGGING TESTS

Test conditions	Test data for indicated runs									
	3	4	5	11	12*	13†	14	15	16	18
Vol % additive	none	none	FSII 0.25	EGME 0.15	none	none	none	none	FSII 0.15	EGME 0.15
Test temp, °F	35	35	35	35	35	35	35	35	35	35
Manometer readings, in. Hg										
Initial at 77°F (calcd)	2.13	2.00	2.92	2.40	2.30	2.49	1.86	2.18	3.75	1.94
Initial at test temp	2.95	2.78	4.05	3.33	3.18	3.45	2.59	3.03	5.20	2.69
Final at test temp	3.11	2.88	16.26	8.19	8.75	8.35	2.79	3.50	11.70	3.11
After warmup	2.60	2.38	8.55	4.25	3.49	3.31	2.19	2.70	4.15	2.30
After warmup (calcd)	2.24	2.08	11.73	5.91	6.31	6.02	2.01	2.52	8.44	2.24
Temp of fuel after warm-up, °F	69	73	75	72	73	75	72	74	74	75

*Fuel was filtered and stored for 18 hr in unlined steel cans before testing
†Fuel was filtered and stored for 2 hr in unlined steel cans before testing

To facilitate comparison, the data of Tables 86 and 87 have been recalculated in terms of the following plugging indexes:

$$P_{35} = \frac{C - B}{B} \times 100 = \text{plugging at } 35^\circ\text{F}$$

$$P_{77} = \frac{D - A}{A} \times 100 = \text{plugging at } 77^\circ\text{F}$$

$$P_t = \frac{E - D}{A} \times 100 = \text{temporary plugging}$$

where

A = initial ΔP at 77°F, calculated

B = initial ΔP at 35°F, actual

C = final ΔP at 35°F, actual

D = ΔP after warmup, actual

E = ΔP after warmup, calculated

Since the calculated values were obtained by the use of a constant viscosity ratio,

$$A = kB$$

$$E = kC$$

when these values are substituted into the expressions for the plugging indexes, it can be seen readily that

$$P_t = P_{35} - P_{77}$$

and that P_{77} is a measure of the permanent component of the plugging. If the plugging in a given case is entirely permanent, as with inorganic solids, then $P_t = 0$ and $P_{35} = P_{77}$. If the plugging, in another case, is entirely temporary, as might occur with waxlike substances, then $P_{77} = 0$ and $P_t = P_{35}$. These idealized relationships will be distorted considerably by inaccuracies in zero-time definition and variations in final warmup temperature, but they provide useful comparisons. Values of the three plugging indexes are given in Table 88.

It will be noted that the first group of tests, on fuel without additive, gave low values for both P_{35} and P_{77} and that the values of P_t were all small negative numbers. The fact that they are negative merely reflects the inaccuracies that have been discussed, since in theory P_t can never by less than zero. When the additive-free fuel was stored in unlined cans after the final filtration (Runs 12 and 13), the index of total plugging, P_{35}, was high, and both the permanent and temporary components (P_{77} and P_t) were large positive numbers. This could be caused by the presence of particulate matter derived from the fuel itself or from fuel-container interactions. The container is suspect in these cases, since Run 15, in which a lined can was used, gave very little plugging. Also, Run 9, at room temperature with the fuel stored in an unlined can, gave a very significant amount of plugging.

All of the tests on fuel containing FSII gave large values of P_{35}. Unfortunately, warmup data were obtained in only two runs, and these were with different concentrations of additive and with different fuel handling procedures. With 0.25% FSII, blending the fuel in an unlined can, both the permanent and temporary components of plugging were significant, as indicated by large positive values of P_{77} and P_t in the single test in which data were obtained. With 0.15% FSII and line-blending the additive in filtered fuel, the single set of warmup data indicated that the plugging was almost entirely temporary.

TABLE 88. PLUGGING INDEXES

Test fuel JP-4, temperature 35°F except as noted P_{35} = index of plugging at 35°F P_{77} = index of plugging at 77°F P_t = index of temporary plugging						
Run no.	Additive	Procedure	P_{35}	P_{77}	P_t	Special conditions
1	none	A	9	---	---	Iso-octane
2	none	A	9	---	---	Iso-octane
3	none	A	5	22	-17	
4	none	A	4	19	-15	
14	none	A	8	18	-10	
15	none	B	16	24	-8	
12	none	B	175	52	123	Fuel stored 18 hr
13	none	B	142	33	109	Fuel stored 2 hr
5	0.25% FSII	B	302	193	109	
6	0.25% FSII	B	161	---	---	
7	0.15% FSII	B	203	---	---	
8	0.15% FSII	B	192	---	---	
16	0.15% FSII	C	125	11	114	
17	0.15% FSII	C	201	---	---	
10	0.15% EGME	B	163	---	---	
11	0.15% EGME	B	146	77	69	
18	0.15% EGME	C	16	19	3	
9	0.15% FSII	B	---	94	---	Room temperature

The data on EGME blends are contradictory in that two tests gave significant amounts of total plugging and one did not. In the two tests by Procedure B (blending in unlined cans), the plugging was indicated to include both permanent and temporary components in the single set of data obtained. In the one test by Procedure C (line blending), the plugging indexes were all low and were quite similar to those obtained in tests without additive. However, this reflects only the readings at the end of the test; the behavior during the test is a definite indication of periodic plugging (compare curve 18 in Figure 20 with the curves in Figure 15). The maximum plugging during the course of this run amounted to P_{35} = 60.

In view of the apparent anomalies introduced by storage of the filtered fuels in unlined cans (Procedure B), the most reliable comparison of effects of additives is given by the data from runs according to Procedures A and C. These data indicate that 0.15% FSII gives a very significant amount of filter plugging at low temperatures, and that most of this plugging is temporary. With 0.15% EGME, significant plugging occurred during the run, but the filter "unblocked" periodically so that the final pressure drop was little more than the initial.

Further light on the nature of plugging is shed by the data on media staining observed after test (see Table 86). Stain spots were clearly evident in all tests on JP-4 containing FSII or EGME but were absent in most tests on uninhibited JP-4 and barely visible on uninhibited iso-octane. Since both components of the FSII (ethylene glycol monomethyl-ether and glycerol) are colorless, it is evident that the material precipitated on the media cannot

consist solely of additive. In the case of the inhibited JP-4, it is very likely that the colored material consists of color bodies extracted from the fuel by glycerol or EGME. It is also possible that products of chemical reaction between glycerol or EGME and trace constituents of the fuel may contribute to the staining. Results from two tests on fuel stored after filtering suggest interactions between the "clean" fuel and the steel container. In the case of the straight iso-octane, the source of the trace staining is not at all clear; it must be derived either from the test fluid or the system, and neither appears to be a likely source.

The possibility of a contribution of free water to media plugging is supported by the AEL free water analyses (see Table 86), indicating traces of free water in most of the low-temperature runs. No effort was made to control the dissolved water content of the test fuel. The amount of dissolved water initially in the fuel at room temperature could easily exceed the saturation value of fuel at 35°F. It is noteworthy that, in each pair of duplicate tests, the test in which more free water was indicated always gave the greater increase in pressure drop:

Run no.	AEL rating	P_{35}
3	0-1	5
4	0	4
7	0-1	203
8	0	192
10	4-5	163
11	0	146
17	2-3	201
16	0-1	125

f. Conclusions

Based on all the data, the best interpretation of the mechanism of media plugging by fuel-FSII or fuel-EGME blends is as follows: When foreign contaminants are absent, media may be partially plugged at low temperatures by liquid, semiliquid, or low-melting solid materials precipitated from the blend. These consist predominantly of glycerol, water, and EGME, along with trace fuel constituents extracted or precipitated by the mixture. If the material is liquid or semiliquid, it coats the fibers of the media and restricts the flow passages. When such material has built up to a certain equilibrium thickness on the fibers it tends to be displaced by the fuel flow and to migrate through and out of the bed; thus, the ultimate degree of plugging by this mechanism is strictly limited. This type of plugging is aggravated by low temperatures, which will tend to increase the amount of precipitated material and also to increase its viscosity; thus, both the plugging rate and the final equilibrium degree of plugging will be greater at low temperatures. Part of the low-temperature effect is reversible; this may be caused by thinning of the semiliquid material (on warmup) and displacement of part of this material from the bed, or it may be caused by melting of waxlike materials.

These experiments have demonstrated that the then-current FSII can give significant plugging of filter media, especially at low temperatures. The pressure buildups that were observed were rather moderate in comparison with those observed in the field. Exact comparisons are difficult because of the poorly defined flow area and flow velocity in these experiments. However, assuming that the 3/8-in.-diameter stains on the media represent the flow area, the superficial flow velocity would be about 4.5 ft/min, or about 2.5 times that in a military-standard element. The greatest pressure drop observed in any of these experiments was about 7 to 8 psi, in comparison with 20-psi plugging observed in the field at lower flow velocities. This discrepancy may well be a function primarily of the lesser thickness of media used in the experiments. In any case, the experiments indicate conclusively that FSII in JP-4 fuel can cause filter plugging, even in the absence of foreign contaminants. In addition, these results suggest the possibility that EGME alone can influence media plugging, although to a lesser degree than when it is present in combination with glycerol.

Under actual storage conditions, fuel reactions resulting in gum precipitation may be a significant factor in low-temperature plugging. In the experiments performed here, short-term storage of filtered JP-4 in unlined cans contributed significantly to filter plugging.

The severe plugging encountered in the field under low-temperature conditions is undoubtedly the result of several factors apart from those investigated here. Fuel corrosion inhibitors may well contribute to plugging, especially if their presence leads to entrainment of trace amounts of water. Finely dispersed iron oxide will obviously contribute to filter plugging under almost all conditions, and it is entirely possible that, in combination with glycerol, fuel gums, and corrosion inhibitors, iron oxide may catalyze condensation reactions that "set" the contaminants in the filter bed.

The work performed here has given an ample demonstration of the role of glycerol-containing FSII in low-temperature plugging and has indicated that elimination of the glycerol should be helpful but may not be a complete solution of the problem.

2. Separometer Studies

a. General

During the course of filter-separator testing, much use was made of separometer tests as an aid in determining fuel characteristics. Results obtained with the separometer often indicated severe inadequacies in its use for rating fuels. One of the main problems seems to be coalescer disk variability. This feature of the separometer test was investigated and has been reported earlier.(5) In addition, many other investigations involving separometer tests were made during this program. Most of these were performed as evaluations of fuel-additive blends. However, a number were concerned primarily with evaluations of the instrument itself, in an effort to make results more accurate and precise. The observations made during those evaluations are reported in this section.

b. WSIM Values of Fuel-Corrosion Inhibitor Blends

In the proposed revision of the fuel corrosion inhibitor specification, MIL-I-25017C, a new requirement has been added in the definition of maximum allowable concentration, namely, a WSIM value of 70 or higher when the corrosion inhibitor is tested in Bayol-toluene reference fluid. Formerly, a WSI (old method) of 87 minimum was required. In order to obtain preliminary data on the WSIM values obtained with currently qualified corrosion inhibitors, a series of separometer tests was run on such blends.

All of the currently qualified corrosion inhibitors except Texaco TRI 182 were included in this series. The TRI 182 is little used and not generally available. A recently qualified material, Tolad 245, was not included in the series, since no sample had been made available by the Air Force.

Tests were run on each inhibitor at maximum allowable concentration as currently defined (without the WSIM requirement). For those inhibitors rating below 70 WSIM, the test was repeated at minimum allowable concentration (relative effective concentration) as currently defined. The following data were obtained:

Corr inhib	Concn., lb/Mbbl, QPL-25017-7*		WSIM in Bayol/toluene at concn. shown	
	Max	Min	Max	Min
duPont RP-2	20	7	66	78
duPont AFA-1	16	4	92	---
Lubrizol 541	20	5	83	---
Tolad 244	20	5.5	46,58	90,80
Santolene C	16	4	84	---
Unicor M	20	9	17	64

*Latest QPL available for MIL-I-25017B.

It will be noted that the RP-2, Tolad 244, and Unicor M gave WSIM values below 70 when tested at the presently allowable maximum concentration. In other words, the maximum allowable concentration would have to be reduced

for these three inhibitors to meet the new MIL-I-25017C. The RP-2, however, is so close to the limit that it could well be rated above 70 WSIM by another test. This points out a certain problem in establishing new concentrations on the basis of the WSIM values since the repeatability and reproducibility are rather poor in this range. It would appear that some statistical definition of WSIM value should be included in the qualification procedure.

Of the additives rating below 70 WSIM at maximum concentration, two were rated at well above 70 at minimum concentration, but the Unicor M was still slightly below 70.

c. Fuel-Corrosion Inhibitor Blends as Separometer Reference Fluids

Another purpose of the WSIM series on corrosion inhibitors was selection of a suitable reference material for separometer calibration. The present blends of Aerosol OT in Bayol/toluene, used for separometer standardization, are judged to be rather artificial; some qualified corrosion inhibitor actually used in fuels would at least represent a material used in the field. The use of a well-defined and relatively pure base stock such as Bayol/toluene is essential for uniformity of the calibration fluids and has the further advantage of eliminating or at least minimizing time-dependent interactions between additive and fuel constituents such as those occurring in ordinary jet fuels.

Of the corrosion inhibitors that were tested, the RP-2 and Tolad 244 gave WSIM values covering the range of most interest, and the Tolad 244 was selected for further work.

Several blends of this additive in Bayol R-34 (without toluene) were prepared and tested, with the following results:

Tolad 244 concn, lb/Mbbl	WSIM in Bayol R-34
0	100
5.5	82
6	79
10	57,71,69
15	55
20	50

Plotting these WSIM values against Tolad 244 concentration, a smooth curve is obtained (Figure 25), with only one point far off the curve. No explanation can be found for this particular deviation, since the coalescer disk weights and standard airflow calibration results were quite similar in the three check tests on the 10 lb/Mbbl blend:

Disk weight, mg		Airflow ΔP, cm H_2O*		WSIM
Coarse	Fine	Coarse	Fine	
100	54	2.4	19.5	57
92	51	2.4	18.6	69
99	46	2.3	19.2	71

*Airflow calibrations were performed in a WSI cell at an airflow rate of 8 ℓ/min.

The lineup of the two higher WSIM values with the other points on the WSIM/concentration curve (Figure 25) indicates that the one low value is less reliable, for reasons unknown.

d. Effects of Media Weight and Media Density

The 10-lb/Mbbl blend of Tolad 244 in Bayol R-34, which corresponds to a WSIM of 70, as reported in the section above, was selected as a reference blend for further studies on media properties in the water separometer.

A series of tests was run to establish the effects of media weight and density on separometer results. Special "unsplit" fine coalescer disks had been received from Emcee. These represent disks made from the fiberglass mat as received and also represent disks that are over-specification in the airflow quality control test, i.e., offer more than the maximum allowable flow resistance when tested singly in an old-type WSI cell. For this study, a modified airflow check procedure was used: The disk or disks were installed in a new-type (WSIM) cell, and pressure drop was checked at the relatively low airflow rate of 155 ml/min. This low air rate was necessary to bring the pressure drops into a workable range when using more than one disk. With this modified airflow procedure, the "unsplit" fine disks from Emcee gave pressure drops from 6.1 to 6.7 cm water with a single disk in the WSIM housing and 16.8 to 18.1 cm water with two disks in the WSIM housing. It should be noted that the airflow pressure drops in most cases are not related to the actual flow resistance of the disks in the subsequent WSIM tests, since the spacers used in the WSIM tests altered the degree of compression of the disks.

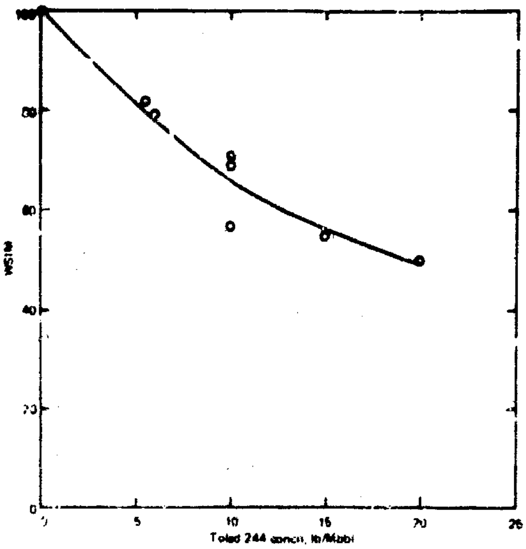

FIGURE 25. EFFECT OF TOLAD 244 ON WSIM OF BAYOL R-34

Single unsplit fine disks were tested in the WSIM cell with the regular compression gap of 0.0625 in. and also with the gap reduced to about 2/3 and 1/3 of the original. Double disks were tested with 0.0625-in. gap and also with about half and twice that gap. Double disks were also tested with the addition of a layer of "sock" material from a military-standard filter-separator element (Filters Inc) as the last stage. Results are listed in Table 89.

TABLE 89. AIRFLOW CALIBRATION AND WSIM RESULTS ON SPECIAL "UNSPLIT" FINE COALESCER DISKS

	Single disk			Two disks			
	A	B	C	D	E	F	G*
Media weight, mg:							
First disk	59.4	58.5	58.3	59.6	59.5	61.2	61.0
Second disk	---	--	---	57.6	58.8	58.8	57.2
Total	59.4	58.5	58.3	117.2	118.3	120.0	118.2
Airflow ΔP, cm H_2O†	6.7	6.4	6.1	16.9	18.1	16.8	17.1
WSIM tests (on blend of 10 lb/Mbbl Tolad 244 in Bayol R-34)							
Compression gap, in.	0.0625	0.0397	0.0195	0.0625	0.1195	0.0303	0.0625
Compressed media density, lb/ft^3	4.6	7.1	14.5	9.1	4.8	19.2	9.2‡
WSIM result	57	52	56	62	62	60	61

*With layer of "filter sock" as final stage
†Airflow checks at 155 ml/min with 1 or 2 coalescer disks in WSIM housing with standard compression gap (0.0625 in.)
‡Not corrected for volume occupied by "filter sock" fabric layer

These results lead to the unexpected conclusion that, for this particular system of media and fuel/additive, the WSIM result is completely insensitive to both media amount and media density. In the series of tests denoted by A, B, and C, a threefold increase in density with the same amount of media gave no significant effect on WSIM. Likewise, doubling the amount of media gave no significant effect (D, E, and F in comparison with A, B, and C). The use of "sock" fabric as the final stage gave no detectable effect. All WSIM values were within the range of 52 to 62, i.e., within the repeatability precision limits of the instrument in this range. It is also interesting to note that none of these values, obtained with fine disks only, was much below the range of 55 to 71 WSIM values obtained on the same fuel blend using standard sets of disks (one fine, one coarse).

Similar tests were run with standard coarse coalescer disks. Airflow checks were run by the standard method (one disk in old-type WSI cell with 8 ℓ/min airflow), by the standard method with two disks in the cell, and by the special method described previously (one or two disks in new-type WSIM cell with 155 ml/min airflow). The airflow and WSIM results are listed in Table 90. With a single coarse disk, at densities from 6.7 to 25.4 lb/ft^3 all WSIM values were within the range of 25 to 29; i.e., there was no effect of media density. With two coarse disks, at densities from 7.1 to 33.5 lb/ft^3, the WSIM values ranged from 26 to 51, with an apparent maximum (optimum) at 13.7 lb/ft^3. The addition of a layer of filter-sock fabric to this "optimum" combination, giving an average density of 22.9 lb/ft^3, dropped the WSIM back to 39.

Thus, for this particular blend of 10 lb/Mbbl Tolad 244 in Bayol R-34, the results with the fine disks indicated no sensitivity whatever to media density or amount over rather wide ranges, and WSIM values about as good as those obtained with the standard fine/coarse combination. With the coarse disks alone, WSIM results were generally at a lower level and showed insensitivity to media density with single disks, but better coalescence and

TABLE 90. AIRFLOW CALIBRATIONS AND WSIM RESULTS ON STANDARD COARSE COALESCER DISKS

	Single disk			Two disks			
	A	B	C	D	E	F	G*
Media weight, mg:							
First disk	87.0	88.0	102.0	91.6	93.9	105.9	108.8
Second disk	---	---	---	85.5	80.9	103.2	92.2
Filter sock	---	---	---	---	---	---	94.3
Total	87.0	88.0	102.0	177.1	174.8	209.1	195.3
Airflow ΔP, cm H_2O:							
Standard†	2.6	2.6	3.2	7.6	7.0	7.6	9.4
Special†	0.08	0.20	0.22	1.00	0.90	1.02	1.44
WSIM tests (on blend of 10 lb/Mbbl Tolad 244 in Bayol R-34)							
Compression gap, in.	0.0625	0.0397	0.0195	0.0625	0.1195	0.0303	0.0625
Compressed media density, lb/ft^3	6.7	10.7	25.4	13.7	7.1	33.5	22.9‡
WSIM result	25	29	28	51	26	39	39

*With layer of "filter sock" as final stage.
†Airflow checks with actual media as shown (1, 2, or 3 pieces); standard checks at 8 ℓ/min in WSI cell, special checks at 155 ml/min in WSIM cell.
‡Average density of composite; does not represent actual density of any specific piece.

some sensitivity to media density with two disks. The generally higher level of WSIM values with the fine disks (in line with the standard WSIM values) suggests that a valid separometer test could be developed using fine disks alone. This would be desirable from the standpoint of the expected improvement in repeatability of results. The fine fiberglass mat is manufactured for use in filters, and the quality control is better than for the coarse disks. Further, the almost total insensitivity of the fine-disk WSIM values to amount or density of media suggests that disk-to-disk variations will not affect the results to the degree observed in the standard WSIM tests. These conclusions are based on tests on only one fuel blend and would require extensive verification before they could be generalized.

e. Effects of Water pH and Hardness

During the early part of the program reported herein, some special separometer tests designed for preliminary exploration of the effect of water pH on coalescence were performed. These tests were performed using JP-4 inhibited with 4 lb/Mbbl of Santolene C (no FSII). This was a hand blend using Ashland uninhibited JP-4 Batch 11*, with Santolene C. The uninhibited fuel was paper filtered (Whatman no. 12) prior to blending; the inhibited blend was not filtered. The tests included a standard WSIM run with distilled water, one run with tap water, and two runs with tap water adjusted to approximately 8.4 and 5.8 pH by addition of small amounts of NaOH and HCl, respectively. In addition, surface tension determinations were performed on the water samples. The data obtained are shown below.

	Water		WSIM
	ST, dyn/cm	pH	
Distilled water	72.9	6.9	97
Tap water	70.3	7.3	90
Tap water + NaOH	72.1	8.3	64
Tap water + HCl	71.5	5.9	98

It will be noted, first of all, that all of the water samples were of good quality in terms of freedom from surfactants, as all showed surface tensions above 70 dyn/cm. The WSIM results show that the alkaline tap water gave a very low WSIM, while the acidic tap water gave a high WSIM, essentially the same as the distilled-water value.

This is of considerable interest in demonstrating the pronounced effect of water quality on interfacial properties where fuel containing an acidic type corrosion inhibitor is involved. The difference between behavior of the distilled water and that of the tap water should not be ascribed to the relatively minor difference in pH, and in fact pH values on distilled water are of little meaning if the water is reasonably pure. Rather, the presence of significant amounts of sodium (and possibly potassium) ions in the tap water is the more probable explanation of this behavior. Raising the pH of the tap water intensifies the interaction of the sodium ions with the inhibitor, and lowering the pH suppresses the interaction to a great extent.

Analytical data on the WPAFB tap water (analyzed in June 1966) are given below. As can be seen, the water is very hard and the sodium content is fairly high, both typical of untreated well water in this area.

	ppm
Iron	0.10
Manganese	0.09
Calcium	99
Magnesium	35
Sodium	19
Potassium	2.2

*Inspection data for this fuel is reported in Reference 7.

	ppm
Bicarbonate	342
Carbonate	0
Sulfate	90
Chloride	36
Fluoride	0.3
Nitrate	0.9
Phosphate	—
Silica	11
Total dissolved solids	462 (calcd)
Total hardness as $CaCO_3$	391
Alkalinity as $CaCO_3$	280
Free CO_2	14
pH	7.6

Although no additional tests of this nature were performed using the separometer, these data were used as a guideline for subsequent work on the Al/SS loop. Unfortunately, loop tests involving injection waters of different compositions failed to support the conclusions obtained with the water separometer. Results of those loop tests are discussed in Section V of this report.

f. Pump Wear Debris

In an effort to determine more precisely the amount of pump wear debris released into sample fuel during regular separometer tests, a special set of evaluations was made. For these evaluations, the coalescer cell on a standard separometer was replaced by a Millipore bomb sampler having a pair of 0.8μ matched-weight membrane filters. A single separometer was used in all tests. After flushing according to standard procedure* with unfiltered solvents (five 200-ml portions of isopropanol followed by five 200-ml portions of Bayol R-34), two tests on Bayol R-34 followed by two tests on uninhibited JP-5 were performed. A volume of 4ℓ of each test fluid was prefiltered (Millipore 0.8μ) on the day of the test and was kept in the dark in scrupulously clean glass containers until used. For each test, a 2-ℓ quantity of the prefiltered fuel was handled exactly as in regular WSIM tests except that no water was added; then most of this fuel was passed through the matched membranes in the sampler. The volume passing through the sampler was measured and recorded. The results of these tests and the solids contents of the refiltered fluids are given below:

Test	Solids, mg	Solids, mg/ℓ	ASTM color rating of test membrane
Bayol, Run 1	0.26	0.15	
Bayol, Run 2	0.53	0.31	
JP-5, Run 1	0.43	0.25	A-2
JP-5, Run 2	0.74	0.43	A-2

Following each run, the test filter was inspected under a microscope. These observations indicated the presence of copper or brass, steel, and Teflon tape of varying particle size on every filter.

It is interesting to note that the two tests on Bayol indicated lower contamination levels than those on JP-5. If the major portion of the solid material were pump wear debris, one would expect more solids in the Bayol runs, since the lubricity of the Bayol is quite poor in comparison to most JP-5 fuels.

*Standard procedure calls for a test-fuel flush after the last Bayol flush; however, for these tests, this step was omitted.

The assortment of debris that was observed on the membrane filters may have come from the unfiltered flush solvents or may have been derived largely from the separometer fuel system itself. In any case, these data suggest the need for better control of system cleanliness and further investigation of contaminants and their possible effect on separometer test results.

g. Flushing Procedure and Effects of Isopropanol

One item of separometer procedure that was investigated during this program was the completeness of flushing. It is known that small amounts of isopropanol remaining in the test fuel will interfere with obtaining correct results. Data obtained in this program indicated that up to 0.4% isopropanol caused only slight decreases in the WSIM values obtained on Bayol/toluene blend with and without 1.0 mg/ℓ Aerosol OT, as shown below:

Additives in Bayol/toluene		WSIM
Aerosol OT, mg/ℓ	Isopropanol, vol %	
0	0	99,99
0	0.1	100
0	0.2	96
0	0.4	94
1.0	0	70,64,64
1.0	0.1	65
1.0	0.2	60
1.0	0.4	57

Later, work was performed to determine the actual residual levels of isopropanol concentration with the instrument flushing procedure that was used. During a separometer test on uninhibited JP-5 base fuel, samples were taken from the separometer tank return line (identical to material being pumped to the test section) at various points in the flushing and test sequence. These samples were analyzed chromatographically for isopropanol content by another laboratory obtaining the following results:

	% isopropanol
Final Bayol flush	0.8
Final test fuel flush	0.03
Test fuel just prior to injecting water to start emulsification	None

Reference analyses on unused Bayol R-34 and unused test fuel also indicated zero isopropanol.

It can be seen that the flushing procedures that were used were adequate to remove isopropanol to below the detectable limit (somewhere under 0.03%). The flushing procedure was slightly more stringent than the ASTM procedure (D 2550-66T) in that an additional test fuel flush was included, and the sequence and technique of flushing were controlled closely. The rather high content of isopropanol in the final Bayol flush, using this closely controlled procedure, suggests that only slightly poorer techniques would result in unacceptably high contents of isopropanol carrying through into the test fuel itself. On this basis, the extra care that was taken in the flushing operations is well justified.

The isopropanol concentration of 0.4% that was mentioned as a satisfactory upper limit was based on tests on Bayol/toluene with and without Aerosol OT. It should not be deduced that 0.4% isopropanol will be equally harmless in other fuel/additive systems. Any mutual solvent such as isopropanol in an emulsifying/coalescing situation, can have profound effects in either direction. The only safe procedure is to remove the isopropanol below the limits of practical detection.

h. Effects of Disk Treatment

During the program reported herein, an effort was made to determine whether washing and/or drying coalescer disks before use would have any effect on separometer rating level and repeatability. In each test in this study, standard coarse and fine disks were used according to standard WSIM procedure. A blend of Bayol R-34 with 10 lb/Mbbl Tolad 244 was used throughout. Before the start of the series, the coalescer disks to be used were inspected visually, weighed, and checked to determine their resistance to airflow. Data obtained are given below:

Coarse Disks

Disk no.	1	2	3	4	5	6	7	8	9	10
Weight, mg	70.4	66.4	74.2	80.0	75.6	98.4	99.6	74.0	98.2	93.7
ΔP, cm H_2O*	2.0	2.2	2.2	2.6	2.6	2.8	3.2	2.2	2.6	2.2

Fine Disks

Disk no.	1	2	3	4	5	6	7	8	9	10
Weight, mg	53.7	47.6	51.0	51.1	47.9	50.5	53.1	47.6	49.6	47.6
ΔP, cm H_2O*	18.6	18.0	18.4	19.0	19.0	17.8	17.8	19.0	17.2	19.0

*ΔP measurements were performed on disks installed in a WSI cell with an airflow rate of 8 ℓ/min.

After the above checks were made, the disks (both coarse and fine) were individually treated as described below:

Disk nos.	Treatment*
1 and 2	Stored in desiccator until used.
3 and 4	Stored in closed container over saturated aqueous solution of Na_2SO_4 until used.
5 and 6	Placed in oven at 147°C for 4 hr, then stored in desiccator until used.
7 and 8	Washed with filtered distilled water, then dried 24 hr at 50°C, then stored in desiccator until used.
9 and 10	Washed with filtered isopropanol then washed with filtered distilled water, then dried 24 hr at 50°C, then stored in desiccator until used.

*Storage times in desiccator or closed container ranged from 47 to 121 hr. Equilibrium can be assumed in all cases.

After the above treatments, the disks were used in separometer tests. Results of these tests, which are shown below, indicate that the repeatability is within the 95% confidence limits specified by ASTM D 2550-66T for all pairs of WSIM values except for disks 9 and 10. WSIM values for disks 9 and 10 differed by 13 units, whereas the allowable difference between the two samples having a mean WSIM of 63.5 is approximately 12 units according to ASTM D 2550-66T.

Disk nos.	WSIM	Mean	Difference between ratings	Max allowable difference between two ratings*
1 and 2	61,65	63	4	11
3 and 4	56,56	56	0	13
5 and 6	64,54	59	10	12
7 and 8	55,67	61	12	12
9 and 10	57,70	63.5	13	12

*As given by ASTM D 2550-66T.

None of the disk treatments gave any significant change in the level of WSIM values.

Based on these results, it appears unlikely that control of disk moisture content or any controlled washing or drying procedures using the current standard disks will give significant improvements in repeatability or changes in rating level.

i. Precision and Effect of Sample Storage

(1) General

Storage tests in various types of containers were run on an inhibited JP-5 fuel blend to determine the effect of storage on WSIM values and, at the same time, to determine the reproducibility of the WSIM values as obtained by SwRI personnel.

The test fuel blend consisted of Ashland JP-5 batch 14 (purchased without inhibitors) plus 0.15 vol % FSII and 16 lb/Mbbl Santolene C. The blend was made by normal procedures in the Al/SS loop (total blend volume about 650 gal); a one-drum quantity was drawn off for this test series into a prerinsed epoxy-lined steel drum. Storage and test conditions are listed in Table 91. The WSIM tests were run with distilled water (standard tests) and with "injection water." The latter is the "Type B" water that was used in early filter-separator testing in the program reported herein. Mean pH, surface tension, and solids content data for this water are presented in Section III of this report.

TABLE 91. WSIM REPRODUCIBILITY AND EFFECT OF SAMPLE STORAGE

Storage container	Days of storage	WSIM, distilled water			WSIM, injection water		
		Appar	Oper	Result	Appar	Oper	Result
Fresh blend		A	1	77	A	1	42
		A	3	60	A	2	82
		A	2	80	B	2	74
		B	2	81	B	1	63
55-gal drum	3	A	4	72	A	4	37
	14	A	5	47	A	5	76
5-gal can	3	A	4	69	A	4	59
	14	A	5	70	A	5	57
1-gal can	3	A	4	30	A	4	29
	14	A	4	46	A	4	36
1-gal jug	3	A	4	75	A	4	52
	14	A	4	77	A	4	81

NOTES:

Storage temperature: 65-68°F

Fuel blend: JP-5 (Ashland) Batch 14 + 0.15 vol % FSII + 16 lb/Mbbl Santolene C

Injection water: Distilled water + Na 45, Ca 36, Mg 8.1, Cl 64, SO_4 32, and HCO_3 119 : [illegible]

Containers:
55-gal drum - steel, epoxy lined, prerinsed
5-gal can - steel, unlined, no prerinse
1-gal can - tinned steel, no prerinse
1-gal jugs - soft glass washed

Apparatus:
A - separometer in Bldg 42-D
B - separometer in Bldg 70 (U D)

(2) WSIM Reproducibility

Looking first at the fresh-blend WSIM results (Table 91), it can be seen that the reproducibility of the four test results run with distilled water (standard WSIM) was reasonable (i.e., "normal"), but the reproducibility of the four test results run with injection water was quite poor.

Interpreting these results in terms of ASTM procedures for limits of uncertainty of the average[11] the following average values and intervals are obtained for 95% confidence limits:

Standard WSIM (distilled water)	74.5±15.6
WSIM with injection water	65.2±27.6

These limits were computed on the basis of standard deviations (using r = 4 as the divisor) and a factor of 1.837 as applicable to 95% confidence limits with four observations.

On this basis, one can say that the "true" or "objective" averages for these two systems are within the indicated ranges with a probability of 0.95. These ranges, rounded to the nearest whole number, are 59 to 90 for the standard WSIM and 38 to 93 for the injection-water WSIM.

Looking at the standard WSIM values (Table 91), it will be noted that the maximum deviation between any two results was 21 units with a corresponding average of 70. The precision criteria listed for this method in ASTM D 2550-66T show a reproducibility of about 20 units at a mean rating of 70. Therefore, it is concluded that the reproducibility represented by the standard WSIM test results reported herein is approximately at the level defined in the ASTM procedure. It is not possible to obtain a statistical comparison of reproducibility because of the limited number of tests (four per series).

It may also be noted that the single value of 60 reported by Operator 3 in the standard WSIM tests was considerably below the other three results, which were grouped very closely around 79 WSIM. However, there is no statistical basis whatever for saying that Operator 3 is "rating low," since only this one test result is available. In the comparison of Operator 1 values vs Operator 2 values, the checks were excellent in the standard distilled-water WSIM tests, but Operator 1 rated lower than Operator 2 in the injection-water WSIM tests. Again, because of the small number of data points, it is not possible to ascribe any quantitative significance to this difference. With regard to the two separometers involved in this work, no significant difference could be detected.

No attempt was made in this work to determine the probable causes of the relatively poor reproducibility of the separometer results. The ASTM procedure itself lists the dimensions of the coalescer cell and the completeness of flushing (isopropanol removal) as two significant factors. The dimensions of the coalescer cells used in these tests were within tolerance. As reported in another part of this section, studies of the completeness of the flushing procedure indicated satisfactory removal of isopropanol.

(3) Effect of Fuel Storage on WSIM

Using the fresh-blend averages and ranges as defined previously, it can be seen that storage in 1-gal cans was the only condition that produced a regular and significant drop in WSIM, either for the standard- or the injection-water tests. There were two low values in the 55-gal drum storage samples, but these were random with respect to storage time and test operator. Therefore, the only firm conclusion that can be drawn is that storage in new 1-gal cans that have not been precleaned will lead to low WSIM values, far below the limits of normal variation. This conclusion had been drawn previously in CRC work, and the results reported herein merely verify the conclusion for the particular fuel blend used in the current work.

It is interesting to note that storage in 1-gal glass jugs gave no significant lowering of WSIM, even though this particular fuel is believed to be somewhat light-sensitive. Possibly, the relatively low storage temperature and the low intensity of light at the indoor storage site contributed to the lack of any observable effects.

There was a possible trend toward "recovery" in WSIM value between 3 and 14 days of storage. No attempt has been made at statistical confirmation; it is obvious from the exceptions to this "trend" that it is at best of doubtful significance. However, there are two logical reasons why such a trend could exist. One of these is the gradual settling out of finely divided solid material during storage, so that the end product is purer than the starting material. The other is the apparently poorer quality (greater surface activity) of the water used in the 3-day evaluations as compared with that used in the fresh-blend and 14-day evaluations. This effect can be seen by comparing surface tension values for all water samples used in this work as shown below:

	Surface tension, dyn/cm		
	Distilled water	Injection water	Operator
For fresh-blend samples	72.2	...	3
For 3-day samples	70.4	68.7	1
For 14-day samples	72.2	72.7	3

Another point that is of interest in the WSIM comparisons is that the injection-water values were not **significantly** lower than the distilled-water values. This statement should not be taken as firm evidence that no effect exists. Rather, it indicates that trends, if they exist, are obscured by the rather poor precision of the WSIM results in this range. For example, in the fresh-blend values, the average WSIM with injection water is some 9 units below that with distilled water, but this is not a significant difference in terms of any reasonable confidence in the WSIM results. The following are the confidence limits corresponding to these fresh-blend data:

	WSIM with distilled water	WSIM with injection water
99% confidence	46-100	15-100
95% confidence	59-90	38-93
90% confidence	63-86	45-86
80% confidence	66-83	51-80
70% confidence	68-81	54-76
50% confidence	71-78	58-72

Even at a 50% confidence level, there is an overlap in the limits, i.e., we cannot even say that the injection-water WSIM is "probably" lower than the distilled-water WSIM.

The only really significant trend shown in the WSIM data was the decrease caused by storage in 1-gal cans. The WSIM values were as follows:

	Fresh	3-day	14-day
Distilled-water WSIM	74 (avg)	30	46
Injection-water WSIM	65 (avg)	29	36

The WSIM decreases from the fresh-blend values are statistically significant, but the apparent "recoveries" from 3 to 14 days are not.

3. Corrosion Inhibitor Concentration Determination by IFT Measurements

A simple method of estimating corrosion inhibitor concentrations would be very valuable in both research and field applications. For some inhibitors, the standard interfacial tension (against distilled water) can be a fair measure of inhibitor content, so long as fuel/additive interactions do not introduce time-dependent variations. For inhibitors such as Santolene C, which do not depress the standard interfacial tension to any great degree, some other method is needed. In the course of single-element testing, it had been noted that Santolene C blends showed much lower interfacial tensions when the distilled water was replaced by WPAFB tap water or synthetic water blends containing appreciable amounts of sodium ion. A study was undertaken to determine whether such interfacial tensions could be used to estimate the amount of Santolene C in fuel blends. The use of tap water appeared undesirable because of possible variations in water quality, and the synthetic water blend used in the single-element testing appeared to be unduly complex for this purpose. Therefore, studies were made of straight solutions of sodium carbonate and bicarbonate, which would be expected to show maximum interactions with the acidic component of Santolene C.

This work of IFT tests to rate additive concentrations was hampered seriously by problems with the laboratory environment. The data listed in Table 92 illustrate the difficulties that were being encountered with repeatability of results. During the testing period, laboratory temperature was 65° to 66°F, and drafts were interfering seriously with the precision of the test. Even under these conditions, the surface tension values for distilled water were quite normal. It may also be noted from Table 92 that the interfacial tension results on Santolene C blends were not affected significantly by using sodium bicarbonate solution in place of distilled water; at the maximum concentration of 16 lb Santolene C per 1000 bbl of JP-5 fuel, the IFT was 31 to 33 dynes/cm with either aqueous material. This is in marked contrast to earlier results on Santolene C blends in JP-4 when tested with tap

TABLE 92. SURFACE AND INTERFACIAL TENSIONS WITH SODIUM BICARBONATE SOLUTION AND SANTOLENE C FUEL BLENDS

	Date	Instrument scale reading, dyn/cm		Corrected value, dyn/cm
		Individual values	Avg	
Surface tension:				
Distilled water	29 Feb 68	77.6,77.8	77.7	73.1
	1 Mar 68	77.5,77.6	77.6	73.0
$NaHCO_3$ solution	29 Feb 68	68.3,68.8	68.6	64.0
	29 Feb 68	77.6,77.7	77.7	73.1
	1 Mar 68	68.5,69.1	68.6	64.0
	1 Mar 68	77.3,77.5,77.5	77.4	72.8
	1 Mar 68	68.5,71.8,78.1,78.2,78.4, 78.6,78.2	75.4	70.8
Interfacial tension with fresh uninhibited JP-5:				
Distilled water	29 Feb 68	39.0,42.7,40.7,38.5,39.3	40.0	41.7
	1 Mar 68	43.1,41.0,41.5,41.7	41.8	43.9
$NaHCO_3$ solution	29 Feb 68	43.1,41.7,42.1,42.7,42.2	42.4	44.6
	1 Mar 68	40.7,41.3	41.0	42.9
Interfacial tension with fresh JP-5 + 4 lb/Mbbl Santolene C:				
Distilled water	29 Feb 68	39.5,33.5,35.4,35.9,38.1	36.5	37.6
$NaHCO_3$ solution	29 Feb 68	37.2,37.5	37.4	38.6
Interfacial tension with fresh JP-5 + 16 lb/Mbbl Santolene C:				
Distilled water	29 Feb 68	32.4,31.3,32.0,33.9,34.5	32.5	33.0
$NaHCO_3$ solution	29 Feb 68	30.6,30.8	30.7	31.0

NOTE: $NaHCO_3$ solution is 163.9 mg/ℓ of reagent-grade chemical in distilled water.

water or with synthetic medium-hardness water; it had been found that either of these waters would give IFT values some 10 dynes/cm below the values obtained with distilled water.

Subsequently, the IFT apparatus (a Fisher Model 21 Tensiomat) was relocated so as to minimize the effects of drafts and vibrations, cleaning procedures were reviewed and made more rigorous, and time sequences in testing were standardized. Sodium carbonate solution (rather than bicarbonate) was adopted in an effort to increase the "spread" of results, that is, the sensitivity of IFT values to concentration of Santolene C. Under these improved operating conditions, no difficulties were encountered in obtaining repeatable surface tension results on either distilled water or carbonate solution, both giving approximately 73 dynes/cm. Interfacial tension values (shown in detail in Table 93) indicated that the repeatability had been improved somewhat. Also, when using the carbonate solution, the IFT values on blends containing Santolene C were far below those obtained with distilled water and appeared to offer a reasonable basis for estimating inhibitor concentrations. This can be seen from the following summary of results, which includes those shown in Table 93 and others obtained at about the same time:

Santolene C concn, lb/Mbbl	IFT, dyn/cm (average values in parentheses)			
	Distilled water		Sodium carbonate, 123 mg/ℓ	
0	44.2,43.0	(43.6)	37.1,36.8,40.9,39.9,33.2	(37.6)
4	42.3,41.0	(41.6)	24.2,30.5,25.4,30.6	(27.7)
8			21.7	(21.7)
12			18.1	(18.1)
16	32.2,35.1	(33.6)	11.0,12.6,12.7	(12.1)

When the IFT values are plotted against concentration, a reasonable correlation band may be plotted covering all of the points (Figure 26, circles). This band is narrow enough that it appeared satisfactory for estimating Santolene C concentrations. However, check results on a freshly prepared series of blends upset the correlation completely. IFT values on these blends vs carbonate solution were as follows:

Santolene C concn, lb/Mbbl	IFT, dyn/cm
0	41.0
2	38.4
4	34.0
8	24.8,25.8
16	20.4,15.9

These results are plotted on Figure 26 as triangles. It can be seen that all of these points fell outside the band established by the previous data. If a band were drawn to take in all the data points, it would be so wide as to be of no value for determining inhibitor concentrations.

It is suspected that the difficulty with the repeatability of the interfacial tension results is a function of many variables. There are believed to be time-dependent interactions between the inhibitor and trace constituents of the base fuel. In addition, variations in interfacial tension values may accompany small changes in the temperature of the system as well as small changes in the pH of the water phase when dealing with fuel-Santolene C blends.

Because studies of this sort constitute a sizable amount of effort, and the immediate problem at hand did not appear to warrant any extensive expenditure of time, no further work along this line was performed.

4. Test Section ΔP Measurement with Canisters Only

During the development of work in this program, it was decided to perform certain tests in the AI/SS loop to establish pressure drops of the test section less element. These values were thought necessary as correction factors in analysis of pressure-drop data, since they could be subtracted from the total pressure drops to give the corresponding

TABLE 93. INTERFACIAL TENSIONS WITH SODIUM CARBONATE SOLUTION AND SANTOLENE C FUEL BLENDS

	Date	Instrument scale reading, dyn/cm		Corrected value, dyn/cm
		Individual values	Avg	
Fresh uninhibited JP-5:				
Distilled water	6 Mar 68	39.7,43.1,43.3,42.6	42.1	44.2
	8 Mar 68	40.5,41.5,40.6,42.3,40.5	41.1	43.0
Na_2CO_3 solution	6 Mar 68	36.4,35.8,36.0	36.1	37.1
	8 Mar 68	35.0,36.6,35.7	35.8	36.8
Fresh JP-5 + 4 lb/Mbbl Santolene C:				
Distilled water	6 Mar 68	39.9,40.6,40.8,40.6	40.5	42.3
	8 Mar 68	38.9,39.8,39.6,39.2	39.4	41.0
Na_2CO_3 solution	6 Mar 68	23.5,24.6,28.1,23.5,23.0	24.5	24.2
	7 Mar 68	29.2,30.8,30.8	30.3	30.5
	8 Mar 68	25.4,25.7,25.6	25.6	25.4
Fresh JP-5 + 8 lb/Mbbl Santolene C:				
Na_2CO_3 solution	11 Mar 68	22.5,22.1	22.3	21.7
Fresh JP-5 + 12 lb/Mbbl Santolene C:				
Na_2CO_3 solution	11 Mar 68	17.1,19.3,21.1,15.6,20.7	18.8	18.1
Fresh JP-5 + 16 lb/Mbbl Santolene C:				
Distilled water	6 Mar 68	30.7,29.9,34.6,32.3,31.5	31.8	32.2
	8 Mar 68	34.7,34.2,34.3	34.4	35.1
Na_2CO_3 solution	6 Mar 68	12.1,11.7,12.6	12.1	11.0
	7 Mar 68	12.5,14.9,13.9	13.8	12.6
	8 Mar 68	13.9,13.6,14.3	13.9	12.7

NOTE: Na_2CO_3 solution is 123 mg/l of reagent-grade chemical in distilled water.

pressure drops of the elements themselves. This approach seemed quite reasonable; however, as will be seen from the subsequent discussion, the situation was not as simple and clear-cut as it would appear.

Both JP-4 and JP-5 were included, and two different canisters were used in this study. Canister A was the unit used in all loop tests through test no. 211, and Canister B was a replacement used in tests 212 through 329. Canister A was still functioning at a satisfactory level at the time of its retirement, but had seen considerable wear and tear during its 211 tests with SwRI and unknown prior history.

Pressure drops were determined with each of these canisters in the regular aluminum test housing, without test element, over a range of flow rates. With no water present in the test housing, some fuel can bypass through the openings in the bottom of the canister; this could conceivably affect the pressure drop. Therefore, some tests were run with a water seal produced by passing in water through the bottom of the housing until the openings were covered. Differential pressure gage readings in all cases were corrected for gage error, using gage calibration data obtained within the same week. The data obtained are listed in Table 94 and shown graphically in Figures 27 and 28.

In the tests run with a water seal in the bottom of the housing, the pressure drops did not differ significantly from those obtained without a water seal, indicating that fuel bypass through the openings (in the absence of a seal) does not influence pressure drops significantly. With the water seal, as the flow rate was increased, large amounts of free water appeared in the effluent fuel. This phenomenon was noted at 20 gpm with the JP-5 fuel and at 39 gpm with the JP-4 fuel. Since the test housing and canisters functioned quite normally with a water seal in regular tests on JP-5 fuel at 20 gpm, it is evident that omission of the element for these pressure-drop checks created a radical change in the flow conditions in the canisters.

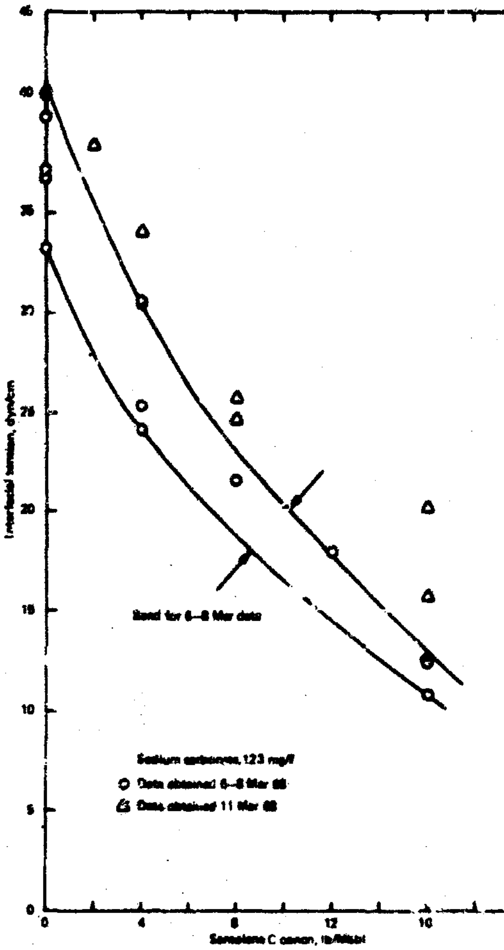

FIGURE 26. INTERFACIAL TENSION (CARBONATE SOLUTION) VS CONCENTRATION OF SANTOLENE C IN JP-5

It can be seen from Figures 27 and 28 that the pressure drop curves on logarithmic coordinates are linear over all or most of the flow rate range. The slopes of the straight-line portions are within the range of 1.8 to 2.0, indicating highly turbulent flow and high Reynolds numbers. This slope, which represents the exponent in the pressure loss vs flow rate function, increases with increasing Reynolds number, reaching 1.8 at a Reynolds number of about 150,000 and theoretically approaching 2.0 as the Reynolds number becomes infinite.

A single check on the pressure drop of the housing alone, with JP-5 at 20 gpm, indicated zero pressure drop. This probably indicates that the actual pressure drop is balanced by a negative velocity-head effect, which is estimated to be 0.3 psi.

It can be noted from Figures 27 and 28 that Canister A, the older of the two, gave slightly lower pressure drops than did Canister B. It can also be noted from these figures and from Table 94 that the JP-5 fuel gave only slightly higher pressure drops than did the JP-4 fuel, in most cases less than 10% higher. This is further confirmation of the turbulent nature of the flow in the areas governing the pressure drop. If the flow were laminar, the pressure drop would be proportional to fuel viscosity and the JP-5 should give about twice the pressure drop of the JP-4. In turbulent flow, pressure drop is approximately proportional to fuel density; this relationship is in reasonable agreement with the results obtained.

TABLE 94. PRESSURE DROP THROUGH HOUSING AND CANISTER

Canister	Water seal	Flow rate, gpm	Pressure drop, psi*	
			JP-5	JP-4
A	No	15	1.6 (1.1)	1.6 (1.1)
		20	2.0 (1.5)	2.1 (1.6)
		25	3.1 (2.6)	2.8 (2.3)
		30	4.2 (3.8)	3.9 (3.5)
		35	5.6 (5.2)	5.2 (4.8)
		37.5	6.0 (5.6)	—
		39	—	6.1 (5.7)
		40	6.8†(6.4)	6.3 (5.9)
A	Yes	15	1.6 (1.1)	
		20	2.2‡(1.7)	
B	No	15	1.6 (1.1)	1.5 (1.1)
		20	2.4 (1.9)	2.2 (1.7)
		25	3.3 (2.8)	2.9 (2.4)
		30	4.4 (4.0)	4.2 (3.5)
		35	5.6 (5.2)	5.6 (5.2)
		38	6.5 (6.1)	—
		39	—	6.6 (6.2)
		40	7.3†(6.9)	6.8†(6.4)
B	Yes	20		2.2 (1.7)
		25		2.9 (2.4)
		30		4.0 (3.6)
		35		5.2 (4.8)
		39		6.5‡(5.1)

GENERAL CONDITIONS:

Uninhibited fuel, inlet temperature 80°F, inlet pressure 70 psig except as noted.

*Corrected values (in parentheses) represent gage readings less gage-error corrections.
†Inlet pressure had to be increased to 73-78 psig to obtain flow rate.
‡Gross amounts of water carried over into effluent.

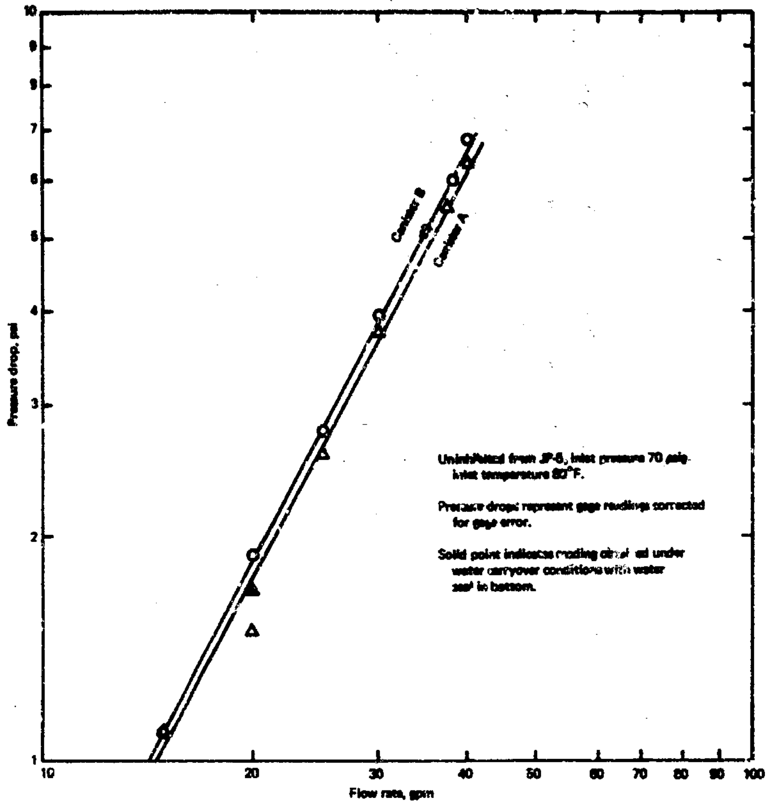

FIGURE 27. PRESSURE DROP THROUGH HOUSING AND CANISTER WITH JP-5

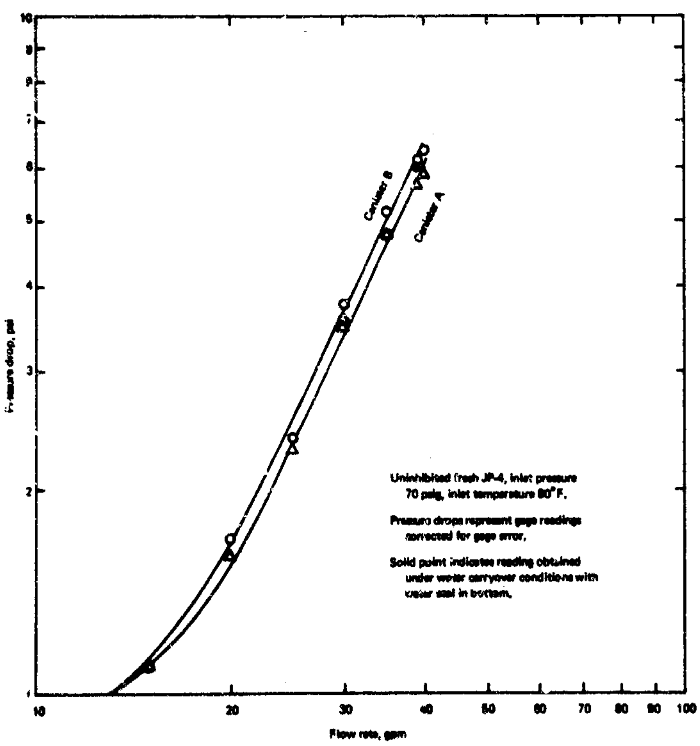

FIGURE 28. PRESSURE DROP THROUGH HOUSING AND CANISTER WITH JP-4

The real reason for performing this work was the need for "blank" pressure drops to subtract from test-section pressure drops, thus giving pressure drops that are characteristic of the test element only. Unfortunately, this approach did not fulfill the objective. The housing-plus-canister pressure drops that were obtained were unrealistically high. For example, at a flow rate of 20 gpm with JP-5 fuel, pressure drops were 1.5 to 1.9 psi with housing and canister, zero with housing only, thus indicating pressure drops of 1.5 to 1.9 psi for the canisters. Total test-section pressure drop is normally 3 to 4 psi with element and canister installed. This implies that the canister is creating approximately as much flow resistance as is the element itself–a conclusion that is obviously incorrect for a number of reasons. In the first place, examining the geometry of the element and the canister, it will be seen that they have approximately the same superficial flow area. The "working layer" of the canister consists of a 100-mesh screen, that of the element of fibrous mat that has considerable depth and consists of tortuous, fine passages. One does not need a detailed mathematical proof to be convinced that the pressure drop across the element should be far greater than that across the canister screen. Again, one may note that the pressure drop we have measured across the canister in this work is 1.5 to 2.0 psi; this refers to about 280 in^2 superficial flow area. Also present in the Al/SS loop is a 100-mesh mixing screen with 2.24 in^2 superficial flow area. Prorating on an area basis, one would predict a pressure drop of 190 to 250 psi across the mixing screen, instead of the 0 to 2 psi actually obtained under these flow conditions. Therefore, it is evident that the observed pressure drops of 1.5 to 1.9 psi cannot be attributed to the canisters.

Considerable theorizing has been done about what was happening, but the end result can best be visualized in physical terms. With the element in place, the high-velocity fuel stream (7 to 8 ft/sec) entering through the bottom connection is diffused through the element and its velocity greatly reduced, so that the flow through the bed is laminar. This picture may break down locally when water enters, but it is probably correct for dry fuel. The fuel leaving the element is essentially in the laminar flow regime. Flow conditions between the element and canister are indeterminate, but in any case there is no time to develop any great turbulence in the 1/16-in. passage between element and canister. Flow through the screen can be calculated to be in the laminar regime, although again conditions are indeterminate because of the changing geometry along the flow path. In any case, there could not be any great turbulence.

With the element removed, on the other hand, the high-velocity fuel stream jets into the canister and creates a condition of extreme turbulence within the whole space. Therefore, flow conditions through the canister screen are quite different when the element is removed, and the "blank" value obtained for pressure drop under these conditions is not a valid blank to use in determining the true pressure drop across the element.

It appears that the unexpectedly high pressure drops obtained with the canister alone are a consequence of a different mode of development of boundary layer at the screen surface when the entering flow is highly turbulent. It is probable that a detailed theoretical analysis of this problem would reveal the cause of the behavior in more precise terms, but this was not essential for the problem at hand.

In order to determine the "true" pressure drop of an element, it would have been necessary to instrument the test section with pressure probes within the center of the element and between the element and canister. The geometry of these components creates certain mechanical problems in installing such probes, and the problem is further complicated by the need to eliminate all effects of flow velocity on static pressure measurement. A more direct approach, and the one that was finally taken, was measurement of element-only pressure drops in separate equipment designed for this purpose, followed by measurement of pressure drop of the test section with this same element installed.

The results indicate that a "blank" correction applicable to all elements cannot be obtained merely by taking the difference between the two pressure readings. The mean difference of these two differential pressures is given below for five different groups of elements:

Element identification	No. of tests	Mean pressure difference*, psi
Bowser	12	3.27
Bendix	12	2.96
Fram	12	3.38
F.I. Govt std	4	2.42
F.I. Lot 516	5	2.24
F.I. Lot 465	38	1.48

*Differential pressure in test section at start of test minus differential pressure in pressure check trough.

From a more general point of view, the data and conclusions reported here could have some significance in interpreting housing and element pressure-drop data on commercial filter-separator equipment. When defining housing vs housing-plus-media pressure drops for specification purposes, tests on the total unit less elements (but

TABLE 95. COLOR RATINGS OF FILTERS IN SOLIDS DETERMINATIONS*

Contaminant: Coarse AC dust																			
Scale:	B																		
Solids	0.00	0.00	0.36	0.34	0.10	0.18	0.11	0.15	0.01	0.30	0.24	0.31	0.52	0.38	0.76	0.38	0.20	0.46	0.42
Rating	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Solids	0.47	0.47	0.04	0.17	0.73	0.32	0.33	0.30	0.44	0.92	0.60	0.40	0.54	0.74	0.14	0.29	0.37	0.64	0.65
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.49	0.77	0.51	0.48	0.48	0.39	0.30	0.39	0.59	0.22	0.71	0.45	0.14	0.34	0.41	0.52	0.22	0.98	0.42
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.10	0.26	0.14	0.31	0.08	0.23	0.36	0.20	0.00	0.00	0.18	0.39	0.40	0.27	0.39	0.65	0.21	1.31	0.42
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.25	0.19	0.28	0.29	0.00	0.00	0.30	0.23	0.34	0.45	0.05	0.00	0.10	0.07	0.16	0.79	0.37	0.26	0.19
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.42	0.19	0.71	0.11	0.21	0.42	0.33	0.26	0.15	0.52	0.21	0.09	0.34	0.35	0.20	0.20	0.51	0.28	0.46
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.70	0.18	0.30	0.48	0.22	0.04	0.49	0.62	0.39	0.74	0.21	0.40	1.28	0.29	0.45	0.42	0.27	0.70	0.22
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.19	0.24	0.28	0.32	0.11	1.00	1.08	0.66	0.36	0.00	0.00	1.26	0.97	0.68	1.57	0.55	1.37	0.74	1.16
Rating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solids	0.00	1.28	0.74	0.63	0.68	0.52	0.57	0.62	0.66	1.53	1.29	1.02	1.51	0.83	0.49	0.87	0.80	0.74	0.81
Rating	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Solids	1.09	1.01	0.60	0.63	0.57	0.44	1.14	0.86	1.08	1.04	0.00	0.47	0.56	0.23	0.18	0.50	0.74	0.74	0.25
Rating	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Solids	0.35	0.38	0.45	0.68	0.00	1.08	0.62	1.87	1.25	0.94	0.86	1.71	1.26	1.04	1.03	1.21	1.87	2.37	2.96
Rating	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3
Solids	2.00	2.56	0.88	0.78	0.96	0.06	1.80	2.27	1.96	1.80	2.34	1.95	1.67	5.52	2.34	5.32	2.76	1.89	1.59
Rating	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4
Solids	2.59	2.50	3.86	2.04															
Rating	4	4	5	5															
Contaminant: Fine AC dust																			
Scale:	B																		
Solids	0.50	0.16	0.00	0.00	0.00	0.12	0.44	0.00	0.34	0.65	0.15	0.91	0.63	2.87	1.99	4.68			
Rating	1	1	1	1	1	1	1	1	1	2	2	2	3	4	4	5			
Contaminant: RIO (Pfizer R-9998)																			
Scale:	A																		
Solids	0.11	0.11	0.00	0.12	0.25	0.22	0.00	0.02	0.00	0.12	0.00	0.24	0.10	0.00	0.11	0.04	0.98	2.74	5.28
Rating	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7	8	9
Solids	9.98	13.50	12.72	12.38	15.92														
Rating	9	9	9	9	9														
Contaminant: Ground Iron Ore (Pfizer B-00985)																			
Scale:	A																		
Solids	0.37	0.31	0.52	0.40	0.56	0.21	0.30	0.36	0.00	0.04	0.28	0.44	1.23	1.36	0.82	0.94	0.82	0.62	0.88
Rating	2	2	2	3	3	3	3	3	3	3	3	4	5	5	5	6	6	7	7
Solids	1.46	2.06	1.52	2.19	2.58	7.32													
Rating	7	7	7	8	8	9													

*All solids determinations were performed using Millipore 0.8μ, 37-mm membrane filters. Solids values given are based on weight gain of test membrane relative to a control membrane used directly below it, and are independent of sample size. Volume of samples which gave these results was 900 to 3900 ml.

with canisters or other separator device) could give fictitious results in the same manner as was observed here. Such effects are probably even more severe in larger equipment.

5. Membrane Filter Color Ratings

In an earlier report(5), membrane color ratings were listed for filters used in solids determinations in conjunction with Al/SS loop tests 225 to 234. Using the same color standards, rating of filter colors was continued through the end of the test program. An examination of the results obtained has provided a number of interesting observations. The greatest value of the ratings appears to be their use as a monitor in detecting contaminants, but they can serve also as a semiquantitative determination when the type of contaminant is known, as in the present program.

The data which are reported in Table 95 were obtained from samples drawn during Al/SS loop tests 225 to 329. In each case, Millipore 0.8μ, 37-mm membrane filters were used.

Results are grouped according to contaminant and rating scale, but no effort was made to arrange results according to additive-fuel combination or to the condition of the fuel, i.e., fresh, clay-treated, or reused. The solids values reported here are the actual amount of solids deposited on the test membrane (in mg) and are hence independent of sample size. A value of 0.00 mg was assigned to those samples which indicated a weight loss of the test filter relative to the control filter.

Four groups of data were obtained during the course of the loop tests, as follows: Coarse AC dust with B scale, fine AC dust with B scale, red iron oxide (RIO, Pfizer R-9998) with A scale, and ground iron ore (GIO, Pfizer B-00985) with A scale. The solids contaminants used are described elsewhere in this report. The color scales used can be described as follows: B-scale, from white at a rating of 0 through light brown to a very dark brown at a rating of 10; A-scale, from white at a rating of 0 through reddish brown to a very dark red (almost black) at a rating of 10. It should be noted that at the zero rating, both scales are the same color.

The mean values of the solids content, along with the standard deviation, and the maximum and minimum values for each given rating are shown in Table 96 and are plotted against the ratings for each group of data on semilog graphs in Figures 29 to 32. As can be noted, the plots can be represented very well by straight lines.

The upper limit of the rating scales is 10, but it is suspected that it is possible to have a smaller upper limit value if the color of the contaminant itself is not as dark as the 10 rating for the scale used. This appears to be the case in Figures 29 and 30, where AC dusts were involved. In both of these cases, no ratings above 5 were obtained and this seems reasonable, because the color of the AC dusts, both fine and coarse, is about the same as that of the 5 rating on the B scale. It is believed that once the solid contaminant has been deposited on the membrane in sufficient quantity to completely cover it, any increase in contaminant will no

TABLE 96. MEAN SOLIDS VALUES AT GIVEN COLOR RATINGS

Solids type	Scale	Rating	Number of samples	Mean solids, mg	SD, mg	Minimum solids, mg	Maximum solids, mg
Coarse AC dust	B	0	12	0.18	0.14	0.00	0.36
		1	142	0.41	0.31	0.00	1.57
		2	46	0.74	0.44	0.00	1.87
		3	20	1.59	0.73	0.06	2.96
		4	10	2.81	1.44	1.59	5.52
		5	2	2.95	---	2.04	3.86
Fine AC dust	B	1	9	0.17	0.20	0.00	0.50
		2	3	0.57	0.61	0.15	0.91
		3	1	0.63	---	---	---
		4	2	2.43	---	1.99	2.87
		5	1	4.68	---	---	---
Red iron oxide	A	0	2	0.11	---	0.11	0.11
		1	14	0.09	0.09	0.00	0.25
		7	1	0.98	---	---	---
		8	1	2.74	---	---	---
		9	6	11.80	3.77	5.28	15.92
Ground iron ore	A	2	3	0.40	0.11	0.31	0.52
		3	8	0.27	0.18	0.00	0.56
		4	1	0.44	---	---	---
		5	3	1.14	0.23	0.82	1.36
		6	2	0.88	---	0.82	0.94
		7	5	1.31	0.57	0.62	2.96
		8	2	2.38	---	2.16	2.58
		9	1	7.32	---	---	---

longer affect the rating and correlation ceases. Therefore, the usable range of the color standards can be a function of the color of the contaminant itself. A look at the results obtained with RIO and GIO tends to support this conclusion. The color of these two contaminants, although not exactly the same, can be matched best by the 9

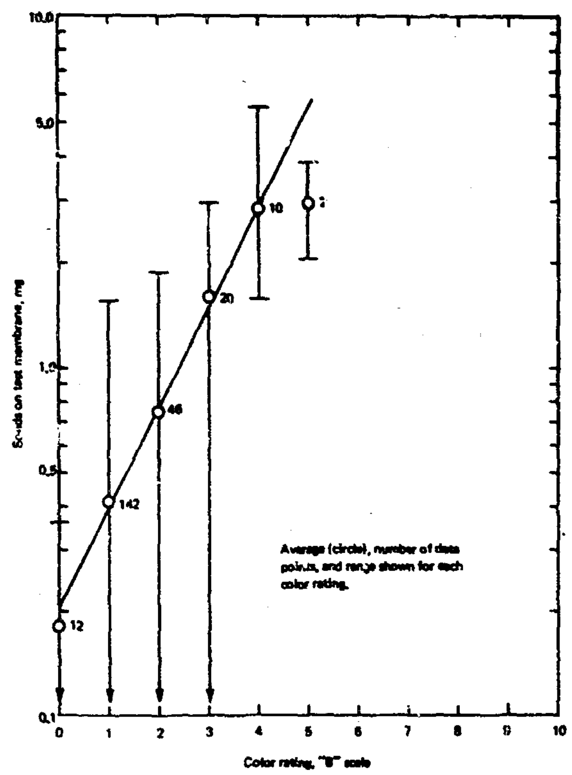

FIGURE 29. AVERAGE SOLIDS VS COLOR RATING FOR COARSE AC DUST AND SCALE B

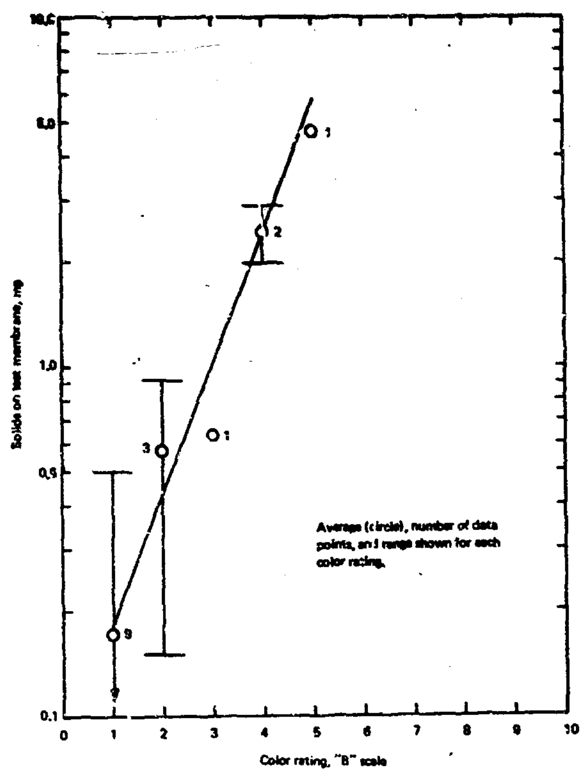

FIGURE 30. AVERAGE SOLIDS VS COLOR RATING FOR FINE AC DUST AND SCALE B

rating on the A scale. No ratings above 9 were obtained for samples containing either of these two solids. If there is indeed a smaller usable rating range for coarse and fine AC dust (0 to 5) than for the RIO and GIO (0 to 9), one might expect the slope of the lines in plots of ratings vs solids to be greater in the case of the light-colored contaminants (range 0 to 5). Figures 29 to 32 do show this to be true. However, this effect may also be a result of the density and particle size distribution of the different contaminants.

Because the data reported here were collected as extra information and not as the result of a carefully planned evaluation of the color standards, they do not lend themselves very well to statistical analysis. Although in every case there appears to be a relatively high degree of correlation between solids content and color rating, it is quite possible that an even higher degree of correlation could be obtained by performing solids determinations while controlling such factors as fuel-additive blend, fuel type, fuel treatment, and fuel free water content. The correlations shown here do point out the potential usefulness of the color ratings in filter-separator testing and related research on fuel decontamination.

6. FSII Determinations

a. Introduction

Analyses for FSII content of test fuels were performed regularly during the Al/SS loop tests using clay-treated fuel. Most of these analyses were run by the differential refractometer method (FTMS-791a Method

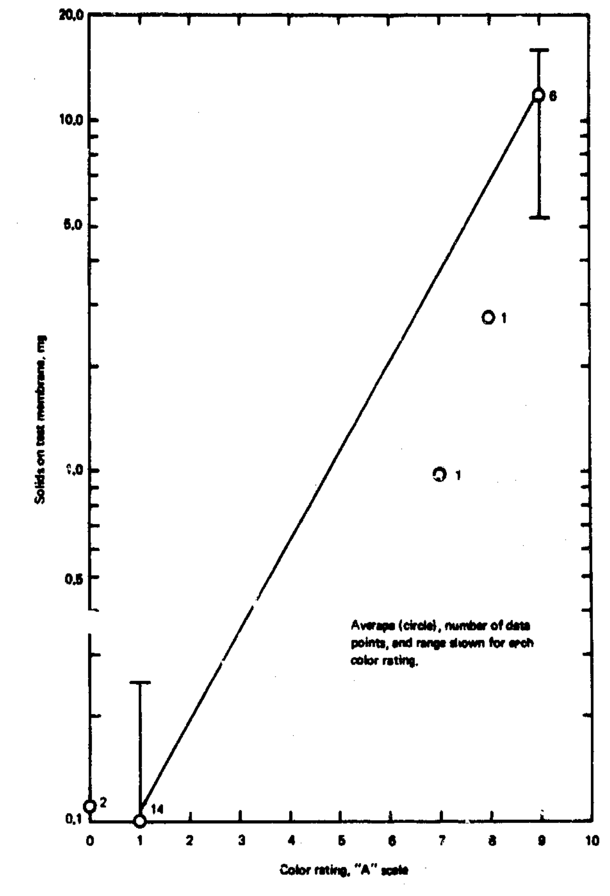

FIGURE 31. AVERAGE SOLIDS VS COLOR RATING FOR RED IRON OXIDE (PFIZER R-9998) AND SCALE A

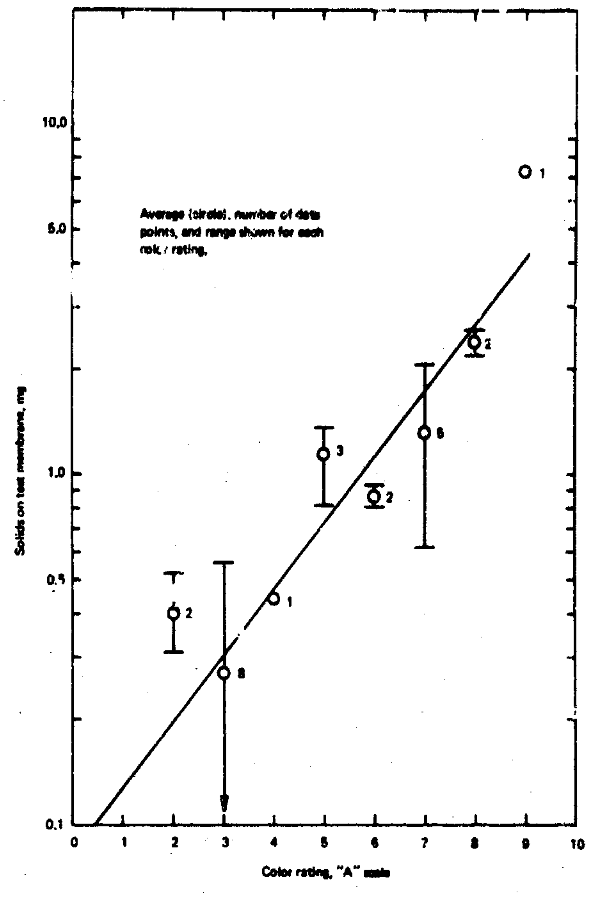

FIGURE 32. AVERAGE SOLIDS VS COLOR RATING FOR GROUND IRON ORE (PFIZER B-00985) AND SCALE A

5340) that is specified in MIL-T-5624G as an alternate for the dichromate-titration method (FTMS-791a, Method 5327.3).* The refractometer method has advantages in time and ease of determination. However, certain problems in technique and ambiguities in the procedure had not been noted, and it appeared further that the method was giving consistently low results. The work reported here was an exploration of these deficiencies and their correction.

In the dichromate method, a 25-ml sample of the test fuel is extracted with 25 ml of water, the aqueous layer is drained off, and an aliquot portion of the aqueous layer is then titrated with standard dichromate solution. The dichromate solution is standardized against known mixtures of FSII and water.

In the refractometer method, an 800-ml sample of the test fuel is extracted with 50 ml of water, and a portion of the aqueous layer is drained off into the refractometer cell. The refractometer reading obtained on this aqueous solution is used, with a calibration curve, to determine the FSII content of the original fuel sample. The calibration curve is established using known mixtures of FSII and water.

Two important points should be noted. First, both methods are predicated on 100% extraction of the FSII from the fuel into the aqueous phase, since the standardization (or calibration) is based on FSII-water blends of known concentrations. Second, the extraction volume ratio of water to fuel is 1/1 in the dichromate method but 1/16 in the refractometer method.

*FTMS-791a was superseded by FTMS-791b in January 1969. However, the two methods in question remained unchanged. Current designations in FTMS-791b are Methods 5327.3 and 5340.1.

b. **Test Materials**

All tests reported herein were conducted with uninhibited JP-5 (Ashland). The FSII was the standard MIL-I-27686D material, consisting of 99.6% ethylene glycol monomethyl ether and 0.4% glycerol.

Normally, FSII is specified for use in JP-4 fuel but not in JP-5. However, the results obtained here with JP-5 are equally applicable to JP-4 so far as the basic comparison of the two methods is concerned. Other work reported here, dealing with relatively minor changes in technique, is strictly applicable to JP-5 or kerosine-type fuels only. When applicability to JP-4 is doubtful, this is so indicated in the test.

c. Initial Calibration Curve for Refractometer Method

Standard solutions of FSII-water were prepared in accordance with Paragraph 4.1 of Method 5340. These solutions are supposedly equivalent to FSII concentrations of 0.05, 0.10, 0.15, and 0.20 vol % FSII in the hypothetical fuel from which the FSII would have been extracted. This supposed "equivalency" is purely arithmetic and is based on the assumption that all of the FSII originally present in the fuel is extracted into the water layer.

Differential refractometer readings obtained on these FSII-water solutions were as follows:

Refractometer reading at indicated volume % FSII in fuel			
0.05	0.10	0.15	0.20
0.57	1.17	1.86	2.52
0.57	1.22	1.86	2.52
0.61	1.25	1.83	2.54
0.56	1.22	1.86	2.53
0.54	1.23	1.88	2.51

The above data were used to plot curve (b) of Figure 33. Curve (a) is the calibration curve furnished by the instrument manufacturer, but it refers to a cell different from the one used in the work reported here. It will be noted that the experimental data give a linear plot (b), as do the manufacturer's data for a different cell.

d. Calibration Curve Established with Standard FSII-Fuel Blends

Six 800-ml blends were prepared with FSII contents of 0 to 0.20% in JP-5 base fuel. Each fuel blend was shaken vigorously in a separatory funnel with 50 ml of water for 3 min. then allowed to settle for 30 sec; a small amount of the water solution was then drawn off and placed in the refractometer cell. This is the standard procedure for Method 5340.* Results were as follows:

Refractometer reading at actual volume % FSII in fuel as shown					
0	0.037	0.075	0.1125	0.15	0.20
0.58	0.69	0.84	1.57	1.74	2.51
0.70	0.42	0.83	1.29	1.82	2.63
0.12	0.41	0.93	1.25	1.74	
0.04					

*The 30 sec settling time is not specified in Method 5340 but is specified in the procedure furnished by the manufacturer of the refractometer.

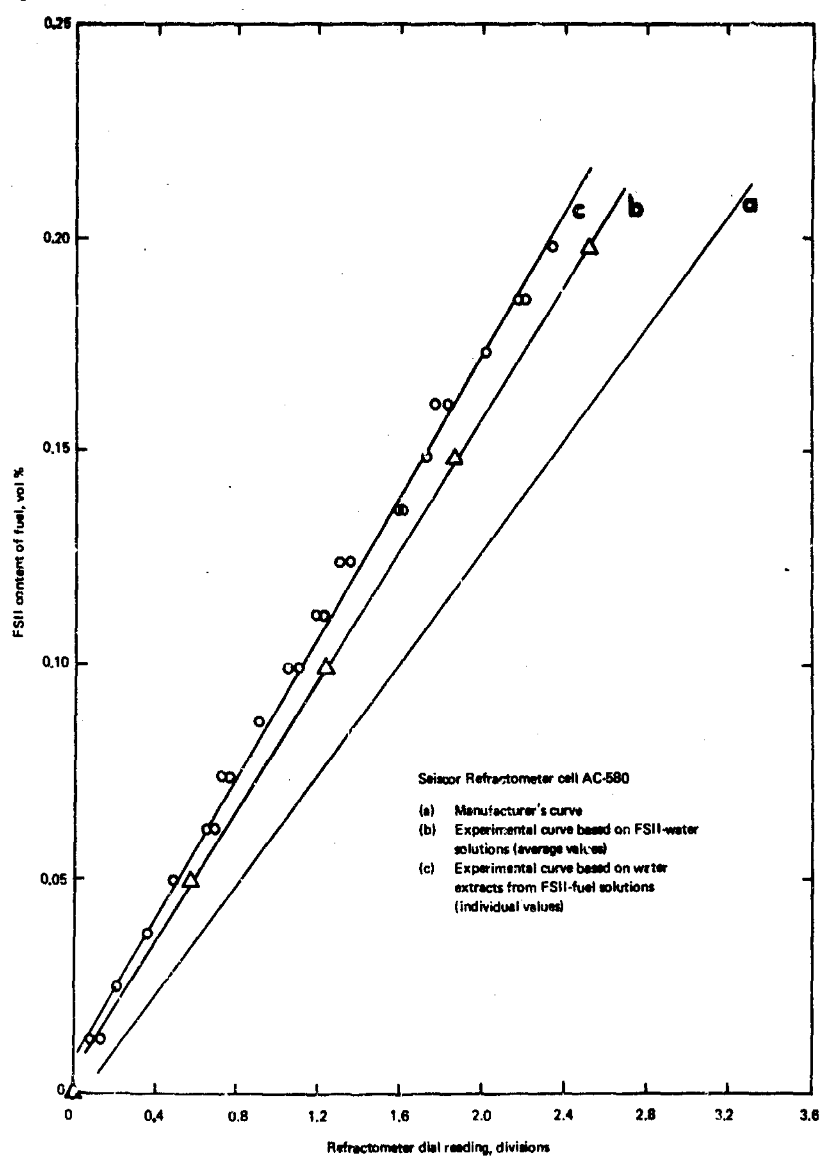

FIGURE 33. FSII CONCENTRATION IN FUEL VS REFRACTOMETER READING

Considerable scatter exists in the above data. This is believed to be the result of horizontal strata or lace-like lines observed in the refractometer cell, probably caused by fuel-contaminated samples. In the extraction step, after 30 sec of settling in the separatory funnel, there was a considerable amount of lacy emulsion in the water layer when fuels containing up to 0.10% FSII were extracted; quite frequently, as much as 1 min of settling time was needed to get a distinct, lace-free interface. At higher FSII concentrations, the interface developed rapidly enough to permit drawing off a water sample free of fuel. Even with a fairly clean separation, there was some tendency to entrain traces of fuel when draining the aqueous layer, presumably because of fuel trapped on the walls of the funnel near the bottom.

In an effort to alleviate this problem, a procedure was adopted in which the aqueous-layer sample was drawn off into a smaller separatory funnel, and additional time was allowed for separation of fuel and water. The addition of a polyethylene needle on the drain tube of the smaller funnel permitted draining the aqueous sample directly into the refractometer cell without any possibility of contact of the needle with fuel. (In the

standard method, a sample of the aqueous layer is drawn into a container, and a portion of this is transferred by syringe to the cell. In this procedure, any traces of fuel in the water sample may contaminate the needle of the syringe.)

Using the revised technique, a number of additional tests were performed; these results, plotted to give curve (c) in Figure 33, are very consistent with little scatter. Curve (c) is seen to lie above the calibration curve (b) that had been established by the standard method using FSII-water blends. This discrepancy between the two curves is attributed to incomplete extraction of FSII from fuel.

If the standard-method calibration curve (b) is used in tests on fuel samples, the indicated FSII concentration is too low by 8 to 12% of the true value obtained from curve (c). At 0.10% actual FSII content from curve (c), the value read from the standard curve (b) is 0.09%, i.e., low by 10% of the true value.

e. Comparison of Modified Refractometer Method with Dichromate Method

Two 825-ml blends of FSII in fuel were prepared, 0.10% and 0.20% by volume. Twenty-five ml of each fuel blend was pipetted out for analysis by the dichromate titration method, and the remaining 800 ml of fuel blend was analyzed by the modified refractometer method. Results of these determinations are as follows:

Actual FSII content, vol %	Indicated FSII content, vol %	
	Refractometer method*	Titration method
0.10	0.101	0.105
	0.103	0.109
0.20	0.205	0.226
	0.206	0.217
		0.205†
		0.203†

*Based on curve (c) (water extracts from fuel).
†Using fresh dichromate solution.

Both methods indicated FSII contents that agreed closely with the known concentrations. It should be noted that these refractometer results are based on the use of curve (c), which had been constructed from data on fuel-FSII blends rather than from the water-FSII blends specified in the regular FTMS method. The results suggest very strongly that the refractometer method should incorporate the use of a calibration curve based on fuel-FSII standards.

f. Discussion

The unduly low results obtained by the **standard** refractometer method (FTMS-791a Method 5340) are undoubtedly caused by incomplete extraction of the FSII from the fuel in the single extraction that is used. Assuming a distribution coefficient of 200/1 for the FSII between the water and fuel phases using 800 ml of fuel and 50 ml of water, 7.4% of the original amount of FSII will remain in the fuel phase. This means that even with very vigorous and long-time shaking to ensure equilibrium, the maximum degree of extraction that can be achieved is only 92.6%. This situation does not exist in the dichromate titration method, where the water/fuel ratio in the extraction is much greater, so that an extraction efficiency of 99.5% can be achieved at equilibrium. Therefore, the standard (FTMS) refractometer method must invariably give lower results than the standard (FTMS) titration method if both procedures are run in accordance with the published test methods. It will be noted that the experimental results reported here are in good agreement with theory. The actual deviations (8 to 12% low) are somewhat greater than the 7.4% predicted by theory, but incomplete equilibration during the extraction and settling could be responsible for the slight additional error in the standard refractometer method. To obtain correct results by the refractometer method, it would be necessary to do one of the following: (a) change to a two-extraction

procedure, (b) establish the calibration curve on the basis of fuel-FSII blends rather than water-FSII blends, as was done here, or (c) apply a correction factor to the results. The use of a correction factor would be undesirable because it would necessarily be based on an *assumed* distribution coefficient that might be in considerable error for some fuels.

If the inherent error in the standard FTMS refractometer method (some 8 to 12%) is a serious drawback to its use for specification and quality control purposes, then the method should be changed along one of the lines indicated above. Calibration based on fuel-FSII blends can be recommended as a sound solution of the problem on the basis of the present experimental work. For maximum precision, the fuel used in calibration should be the same as the fuel being analyzed.* Any other solution of the problem would require further experimental work.

The inherent error in the standard FTMS refractometer method is present whether JP-4 or JP-5 fuel is being analyzed, since these two fuels are quite similar in FSII-fuel-water distribution coefficient. Deviations in distribution coefficient within a given grade (JP-4 or JP-5) are probably greater than the deviation between "average" JP-4 and "average" JP-5. Other things being equal, the FSII distribution coefficient (C_{water}/C_{fuel}) should decrease with increasing content of aromatic hydrocarbons.

Thus, it is a near certainty that the situation with JP-4 will be analogous to that with JP-5, in that the standard FTMS refractometer method will give results that are significantly lower than those obtained by the standard FTMS dichromate-titration method, the latter being much closer to the true values.

Some modifications in extraction technique, such as those described previously, are necessary for use with JP-5 fuel. Such modifications may or may not be necessary for use with JP-4 fuel, which separates from water more readily. However, JP-4 with corrosion inhibitors may also offer problems in separation of the aqueous layer. It is suggested that the FTMS method should incorporate specific instructions on how to avoid contamination of the drain water with fuel. For example, when shaking liquids in a separatory funnel, it is normal practice to vent the funnel periodically by opening the drain while the funnel is in an inverted position. If there is any pressure buildup, this venting will force fuel-water mixture into the drain tube, resulting in contamination of the final drain water. Such venting is obviously undesirable, and the procedure should describe a different venting technique. The use of a second separatory funnel equipped with a needle on the drain line (as described in this report) appears to be a very worth-while modification.

g. Conclusions and Recommendations

It has been demonstrated that the refractometer method for FSII content (Method 5340) gives results some 10% lower than the true values when used on JP-5 fuel without corrosion inhibitor. This discrepancy is caused in large part by incomplete extraction of the FSII from the fuel regardless of shaking time, since equilibrium theory predicts about 93% extraction as the maximum possible. It is a virtual certainty that the same consideration will apply to JP-4.

When the refractometer calibration curve is based on FSII-fuel standards rather than the FSII-water standards specified in Method 5340, the results give good checks with the true FSII contents and with the results obtained by dichromate titration (method 5327.3).

With JP-5 fuel, modifications of the extraction and separation technique are necessary to ensure fuel-free drain water. Such modifications may be necessary and are certainly desirable for JP-4 fuel, particularly for JP-4 containing any corrosion inhibitor that interferes with fuel-water separation.

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*It is recognized that such calibration would be difficult in many cases, when the corresponding additive-free fuel is not available. In such cases, calibrations could be based on a fuel of the same grade (e.g., JP-4) approximating an "average" fuel for the grade. Alternatively, a portion of the test fuel itself could be extracted with sufficient water to remove essentially all the FSII, then reblended with FSII to make the standard blends. This method would be precise but time-consuming.

For analysis of JP-5 fuel by the refractometer method, it is recommended that all of the modifications described herein should be adopted. This applies to any filter-separator test work involving JP-5 containing FSII, and to any analysis of kerosine-type fuels for FSII content.

For analysis of JP-4 fuel, it is recommended that Method 5340 should be changed so that the calibration curve is based on FSII-fuel standards rather than on FSII-water standards.

7. Static Electrification

a. General

The generation of static charge in jet turbine fuels flowing at high velocity presents a serious hazard in transporting and storing fuel. Charge generation rates are especially high in fuel passing through filter-separators

Two methods of minimizing the static charge hazard are as follows:

- The use of antistatic additives which serve to increase fuel conductivity and hence increase the rate of static charge dissipation.
- The incorporation in the flow system of a device which bleeds off the static charge to ground.

In the static electrification program reported herein, both methods were evaluated. A total of 16 tests were run on the following fuel blends:

Uninhibited JP-5

JP-5 + 0.2 ppm ASA-3

JP-5 + 1.0 ppm ASA-3

JP-5 + 4 lb/Mbbl AFA-1

JP-5 + 4 lb/Mbbl AFA-1 + 0.2 ppm ASA-3

JP-5 + 4 lb/Mbbl AFA-1 + 1.0 ppm ASA-3

Static charge generation was effected by passing the fuel through a filter-separator. After leaving the filter-separator, the fuel passed through a device known as a Static Charge Reducer. Static charge density was measured before and after the Static Charge Reducer.

b. Apparatus and Procedures

The major components of the Static Charge Reducer test setup were as follows:

Static Charge Reducer, A. O. Smith, Model SCR-6-36

Sensor Housing, A. O. Smith, Model H-44

Sensor Housing, A. O. Smith, Model H-4-10

Sensor Drive Head, A. O. Smith, Model SD-1

Electrometer, A. O. Smith, Model E600B

Temperature indicator, Yellow Springs Instrument

Strainer, Brodie, Model D-6, size 6

Flowmeter, totalizing, Brodie, Type B-820-BC

Filter-separator, Fram, Model FCS 1259-12E2

The static electrification tests were all conducted using the apparatus shown schematically in Figure 34. Fuel from one of the 15,000-gal underground storage tanks was circulated through a 600-gpm pumping loop and returned to the same storage tank. Fuel from the loop was diverted through the static electrification test bypass, encountering in succession a bucket strainer, flowmeter, filter-separator, charge-density sensor housing, Static Charge Reducer, and a second charge-density sensor housing.

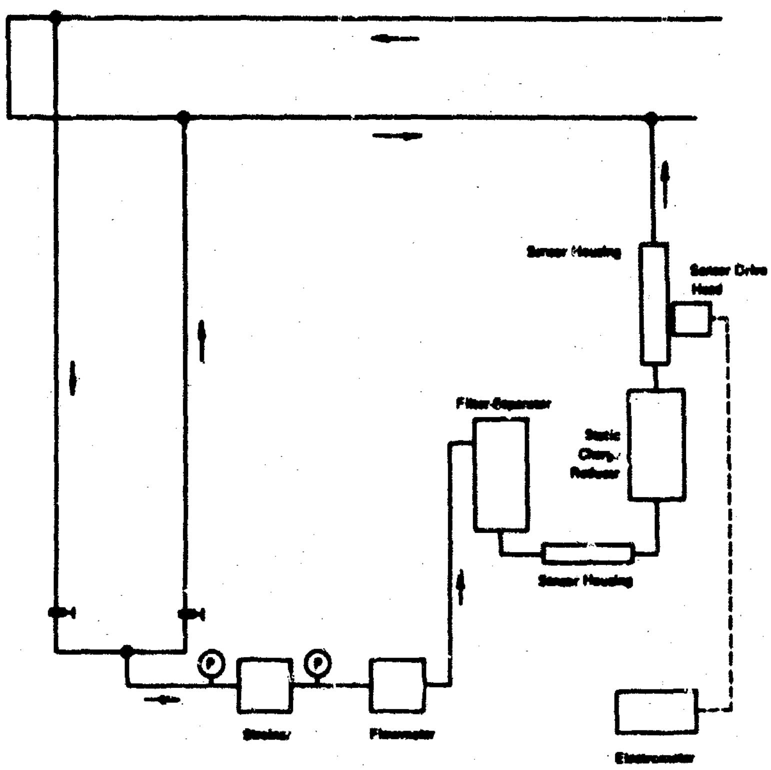

FIGURE 34. DIAGRAM OF STATIC CHARGE REDUCER TEST SETUP

The effectiveness of the Static Charge Reducer (SCR) was determined by measuring the charge density of fuel entering and leaving the SCR. Charge density was determined by measuring the current flowing from a sensor housing through the sensor drive head to the electrometer. A single sensor drive head was used in these tests and was moved back and forth between the two sensor housings. Current measurements were converted to charge density (microcoulombs/m^3) by means of a multiplication factor (7.7×10^9) provided by the manufacturer.

In preparation for these tests, the filter-separator was disassembled, steam-cleaned, and assembled with new elements.

The sequence of procedures used in the tests was as follows:

- A fuel blend was prepared by injecting the additive into the circulating fuel by means of a 1/4-in. stainless steel line from the additive metering system of the AI/SS loop; the metering system is described in an earlier report.[3] The additive was injected at a rate corresponding to the final use-concentration. The injection point was in the fuel line entering the filter-separator. After additive injection was completed, fuel flow was continued to give two complete turnovers of the tank contents.
- The temperature and conductivity of the fuel in the storage tank were measured.

- Fuel flow was started, and the desired flow rate was established during a 15-min pre-test period.

- Without interrupting fuel flow, a 30-min test was performed. During the test period, the fuel temperature, fuel charge density before and after the SCR, and pressures before and after the strainer were measured at 10-min intervals.

- The temperature and conductivity of the fuel in the storage tank were measured again, 45 min after stopping fuel flow.

The first eight tests were run using 15,300 gal of JP-5 (batch 24). The test fuel volume includes 14,200 gal in the storage tank plus an estimated 1,100 gal of fuel holdup in the sections of the loop below the storage tank fuel level. After completion of the eight tests, the fuel was scrapped, and the storage tank, 600-gpm loop, and static electrification bypass were flushed with two 5,000-gal loads of uninhibited JP-5. Each flush load was circulated through the system for 2 hr at 600 gpm.

The last eight tests were run using a test fuel volume of 11,500 gal of JP-5 fuel (batch 25).

Two additives were used in these tests: Shell anti-static additive ASA-3 at 0.2 and 1.0 ppm (wt) and duPont corrosion inhibitor AFA-1 at 4 lb/Mbbl.

c. Test Results

Individual test results are given in Table 97. Examination of the table reveals that both the flow rate and the static charge density measurements remained nearly constant during each 30-min test.

Conductivity of the fuel in the storage tank was measured before and after each test. These measurements differed very little; therefore, the means were used for correlating the data. A plot of static charge of fuel entering the SCR (or leaving the filter-separator) vs fuel conductivity (Figure 35) shows that, for tests at nominal flow rates of 300 and 600 gpm, there is negative linear correlation between static charge and fuel conductivity. Regression and correlation calculations were performed with the following results:

Nominal flow rate, gpm	Regression equation	Correlation coefficient	Probability of a larger correlation coefficient by chance, %
300	$y = -3.01x + 270$	−0.82	2-5
600	$y = -3.82x + 416$	−0.89	0.1-1

The results are in agreement with the known effects of fuel conductivity and flow rate on static charge generation. Charge generation decreases with increasing fuel conductivity and increases with flow. Possibly better correlation would have been obtained if the flow rate could have been set more precisely. The principal problem in setting flow rate was the flow rate measurement. Flow rate was determined by reading the flowmeter at 10-min intervals. The rapidly changing numbers on the meter, especially at higher flow rates, made readings difficult.

It should be emphasized that the two regression lines plotted in Figure 35 are strictly applicable only to the particular fuel blends, conditions, and equipment used in these tests. The behavior of similar blends would probably be characterized by different regression equations even under identical conditions. Also, the design and condition of filter-separator elements, the free water and solid contaminant concentrations in the fuel, and the fuel temperature would all affect static charge generation.

Fuel temperature rise ranged from 0.7° to 2.3°F in these 30-min experiments, and there was no correlation between temperature rise and fuel flow rate.

TABLE 97. STATIC ELECTRIFICATION TEST DATA

Test no.	Additives in JP-5 fuel		Conductivity*, pico-mho/m and temp (°F)		Blend age, hr	Test time, min	Flow rate, gpm	Temp, °F	Strainer outlet pressure, psi	Static charge density, μC/m³	
	ASA-3, ppm	AFA-1, lb/Mbbl	Before test*	After test†						Before SCR	After SCR
1	0	0	0(–)	0(68)	–	0	–	78‡	12	–408	0
						10	–	78‡	12	–408	0
						20	–	79‡	12	–408	0
						30	280	79‡	12	–408	0
2	0	0	0(–)	0(–)	–	0	–	80‡	30	–500	0
						10	610	80‡	28	–492	0
						20	610	80‡	28	–492	+15
						30	610	81‡	28	–492	+15
3	0.2	0	25(71)	(–)	24	0	–	71	28	–154	0
						10	620	72	26	–154	0
						20	550	72	26	–146	–15
						30	590	72	26	–146	–15
4	0.2	0	25(71)	(–)	48	0	–	72	12	–108	+7
						10	310	72	12	–100	+7
						20	310	72	–	–93	+7
						30	310	73	–	–93	+7
5	1.0	0	105(72)	105(72)	24	0	–	72	26	–7	+12
						10	570	73	26	–7	+19
						20	570	73	26	–7	+19
						30	580	73	26	–7	+21
6	1.0	0	100(72)	105(74)	28	0	–	74	12	+15	+15
						10	250	74	12	+19	+15
						20	250	74	12	+19	+15
						30	250	74	12	+19	+15
7	1.0	4	90(75)	95(75)	16	0	–	75	30	–123	+31
						10	610	75	30	–123	+15
						20	610	75	30	–123	+15
						30	610	76	30	–123	+15
8	1.0	4	95(75)	95(76)	18	0	–	74	12	+15	+23
						10	250	76	12	+19	+27
						20	250	76	12	+19	+23
						30	250	76	12	+12	+19
9	0	0	10(69)	9(74)	–	0	–	72	34	–423	0
						10	590	73	34	–431	0
						20	590	74	34	–438	0
						30	590	75	34	–423	0

TABLE 97. STATIC ELECTRIFICATION TEST DATA (Cont'd)

Test no.	Additives in JP-5 fuel		Conductivity*, pico-mho/m and temp (°F)		Blend age, hr	Test time, min	Flow rate, gpm	Temp, °F	Strainer outlet pressure, psi	Static charge density, μC/m³	
	ASA-3, ppm	AFA-1, lb/Mbbl	Before test	After test†						Before SCR	After SCR
10	0	0	10(73)	9(74)	---	0	---	75	19	−269	0
						10	280	75	19	−269	0
						20	300	76	19	−269	0
						30	300	76	19	−262	0
11	0	4	10(83)	10(84)	3	0	---	84	34	−400	−38
						10	630	84	34	−400	−15
						20	630	85	34	−392	−15
						30	620	85	34	−392	−15
12	0	4	10(84)	15(86)	5	0	---	85	47	−392	−15
						10	610	86	34	−384	−8
						20	610	86	34	−384	−8
						30	610	86	34	−377	−8
13	0.2	4	30(81)	35(82)	2	0	---	82	34	−270	0
						10	580	82	34	−262	0
						20	580	83	34	−262	−15
						30	580	83	34	−254	−8
14	0.2	4	30(79)	25(78)	97	0	---	78	19	−115	0
						10	300	78	19	−108	0
						20	300	78	19	−123	0
						30	300	79	19	−115	0
15	1.0	4	45(80)	40(81)	2	0	---	81	39	−246	0
						10	620	81	39	−239	−15
						20	620	82	39	−239	−8
						30	620	82	39	−239	−8
16	1.0	4	40(81)	(−)	5	0	---	81	20	−100	−8
						10	320	82	20	−100	−8
						20	320	82	20	−100	−8
						30	320	83	20	−100	−8

*Measured by means of Maihak conductivity meter.
†Measured 45 min after fuel flow was stopped.
‡Readings may be too high due to faulty battery in temperature indicator.

The basket strainer outlet pressure is, for all practical purposes, the same as the inlet pressure to the filter-separator. This pressure increased with flow rate, as would be expected. Pressures at nominal flow rates of 300 and 600 gpm ranged from 12 to 20 psi and 26 to 39 psi, respectively.

Examination of the condensed test results (Table 98) shows clearly that the SCR effectively reduced the static charge density of the fuel passing through it. The greatest reduction in static charge density occurred in two tests using uninhibited JP-5 at 600-gpm nominal flow rate. In these two tests, static charge density was reduced from −492 and −429 microcoulomb/m³ before the SCR to +8 and 0 microcoulomb/m³ after the SCR. In the remainder of the tests, static charge density in the fuel entering the SCR was lower, apparently because of lower flow rates and/or the presence of ASA-3. For all fuel blends tested, the static charge density of fuel leaving the SCR was less than 30 microcoulombs/m³ which is generally considered to be a "safe" maximum, below which there is slight danger of ignition due to sparking.

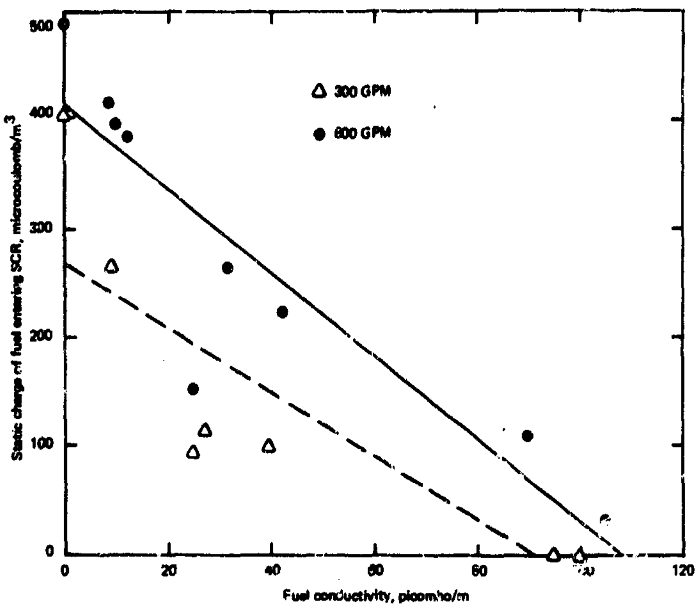

FIGURE 35. STATIC CHARGE OF FUEL ENTERING SCR VS CONDUCTIVITY

TABLE 98. EFFECT OF STATIC CHARGE REDUCER ON STATIC CHARGE DENSITY OF VARIOUS FUEL BLENDS

Additives in JP-5 fuels		Nominal flow rate 300 gpm			Nominal flow rate 600 gpm		
ASA-3, ppm	AFA-1, lb/Mbbl	Test no.	Avg static charge density, μC/m³ Before SCR	After SCR	Test no.	Avg static charge density, μC/m³ Before SCR	After SCR
0	0	1	−408	0	2	−492	+8
		10	−266	0	9	−429	0
0.2	0	4	−99	+7	3	−150	−7
1.0	0	6	+18	+15	5	−7	+18
0	4		---	---	11	−396	−21
					12	−384	−10
0.2	4	14	−115	0	13	−262	−6
1.0	4	8	+16	+23	7	−123	+19
		16	−100	−8	15	−241	−8

The effect of ASA-3 concentration on static charge buildup is shown in Figures 36 and 37. In Figure 36, the static charge density of the fuel just before entering the SCR is plotted against flow rate for JP-5 with and without ASA-3 additive. The level of static charge density decreases significantly as ASA-3 concentration increases from 0 to 0.2 and 1.0 ppm. The decrease in charge density does not appear to be proportional to ASA-3 concentration over the concentration used in these tests. The decrease in static charge density effected by the first 0.2 ppm of ASA-3 is more than twice the decrease resulting from an additional 0.8 ppm ASA-3. Optimum concentration of ASA-3 in this case is evidently somewhat under 1.0 ppm.

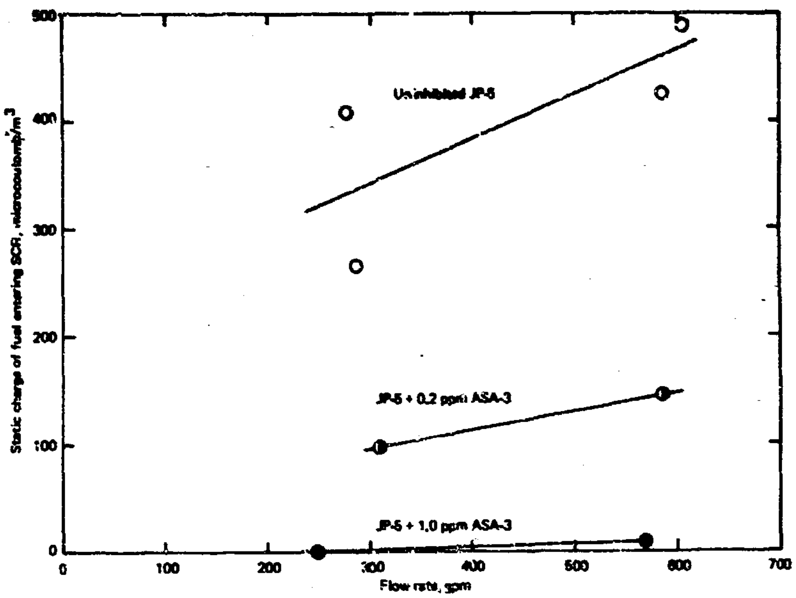

FIGURE 36. STATIC CHARGE OF FUEL ENTERING SCR VS FLOW RATE FOR JP-5 WITH AND WITHOUT ASA-3

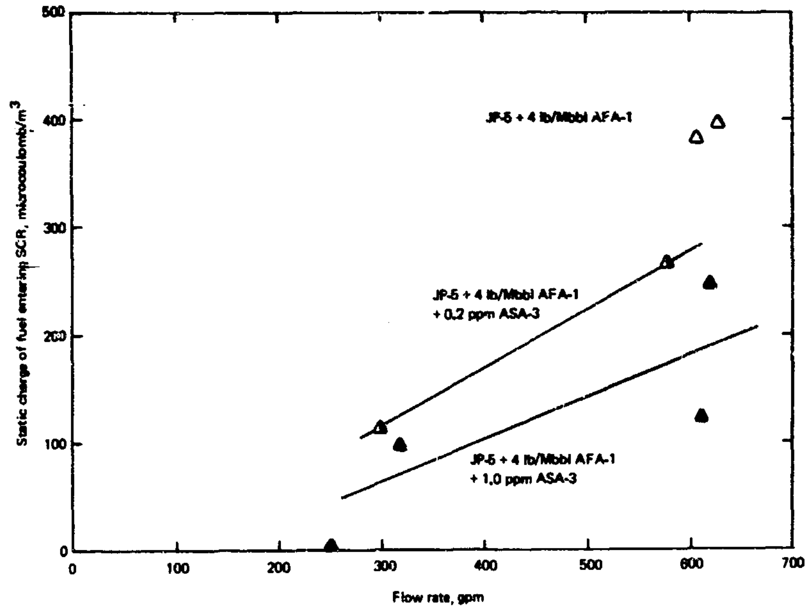

FIGURE 37. STATIC CHARGE OF FUEL ENTERING SCR VS FLOW RATE FOR JP-5 + 4 LB/MBBL AFA-1 WITH AND WITHOUT ASA-3

In Figure 37, similar plots of static charge density vs flow rate are shown for JP-5 fuel + 4 lb/Mbbl AFA-1, with and without ASA-3. Again, successive additions of ASA-3 result in appreciable decreases in static charge density. However, the presence of 4 lb/Mbbl AFA-1 appears to decrease the effectiveness of the ASA-3 in reducing charge buildup. In this case, an ASA-3 concentration somewhat greater than 1.0 ppm appears to be necessary for reduction of static charge density to within the 0 to 30 microcoulomb/m^3 range.

The repeatability of results was reasonably good, judging by the limited number of duplicate test results available. So far as the "after SCR" charge densities are concerned, little difference existed and all were below 30

microcoulombs/m³. The "before SCR" charge densities, reflecting the behavior of the fuel-additive combinations, showed some fairly large deviations between the results of duplicate tests:

	300 gpm		600 gpm	
	First test	Second test	First test	Second test
No additive	–408*	–266	–492*	–429
AFA 4 lb	---	---	–396	–384
AFA 4 lb, ASA 1 ppm	+16*	–100	–123*	–241

*Fuel batch 24; others batch 25.

In the tests with uninhibited fuel, the charge densities were smaller in the second test than in the first test, but of the same sign and same order of magnitude. The difference may reflect different behavior of the two batches of fuel.

In the tests with corrosion inhibitor only, two successive tests on the same fuel blend gave very close agreement of charge densities.

In the tests with corrosion inhibitor and antistatic additive, the second test at each flow rate gave a larger charge density (in the negative direction) than did the first test, and there was one reversal of sign between the two tests. This difference may reflect variations in the blending schedule and the age of the blends when tested. Cumulative ages of the blends are listed in Table 99. In the first series (batch 24 fuel), the final blend with 1 ppm of antistatic additive and 4 lb/Mbbl of corrosion inhibitor had been up to full strength in antistatic additive for 48 to 50 hr and had contained corrosion inhibitor for 16 to 18 hr; for the second series (batch 25 fuel), the respective ages were 2 to 5 hr and 166 to 169 hr.

TABLE 99. CUMULATIVE BLEND AGES OF FUEL USED IN SCR TESTS

Test no.	Time after bringing additive to indicated concentration, hr		
	ASA-3		AFA-1
	0.2 ppm	1.0 ppm	4 lb/Mbbl
Batch 24 fuel			
1	---	---	---
2	---	---	---
3	24	---	---
4	48	---	---
5	144	24	---
6	148	28	---
7	168	48	16
8	170	50	18
Batch 25 fuel			
9	---	---	---
10	---	---	---
11	---	---	3
12	---	---	5
13	2	---	48
14	97	---	143
15	120	2	166
16	123	5	169

d. Conclusions

Based on the test results, the major conclusions are as follows:

- The Static Charge Reducer effectively reduced the static charge density of all fuel blends tested, both at 300-gpm and 600-gpm nominal flow rates.
- The antistatic additive ASA-3 was very effective in minimizing static charge buildup in uninhibited JP-5, somewhat less effective in the presence of AFA-1 corrosion inhibitor.

It should be noted that all of the evaluations in this program were based on measurements of charge density in a short flow line, without any relaxation chamber or receiving tank in the test system. Therefore, the program did not provide any information on the relative performance of fuels and additives in systems including such components.

8. Solids Determinations with Silver Membrane Filters

During the development of analytical techniques for the determination of solid content in both fuel and water samples, studies were made of the applicability of silver membrane filters. Earlier data had indicated that the 0.8 μ membrane filters specified for solids determinations on fuels contain significant amounts of water-soluble plasticizers and are highly unsuitable for analysis of water samples. Silver membrane filters of equivalent pore size (Selas Flowtronics 0.8 μ) were obtained and tested, and were found to exhibit superior performance in filtering water samples. Early in this program, they replaced the Millipore membrane filters in the determination of injection-water solids content.

An attempt to adapt these same silver filters for use with fuel samples produced discouraging results. When the silver filters were tested with a few samples of fuel known to contain red iron oxide (Fisher I-116), passage of significant amounts of the contaminant was observed. Although no quantitative data were obtained, the amounts of red iron oxide passing into the filtrate were obviously greater than expected with the standard 0.8 μ filters, and were sufficient to eliminate the silver filter from further consideration in fuel analysis. The better retention of the standard, nonmetallic membrane filters (with the same nominal pore size) is suspected to be a function of static charge buildup, but this phenomenon was never investigated sufficiently enough to produce any concrete conclusions.

For analysis of water samples, static charge buildup cannot be a factor in retention, and the use of the silver filters is justified.

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APPENDIX

SINGLE-ELEMENT TEST DATA

TABLE 100. SINGLE-ELEMENT LOOP TEST NO. 243 Date: 14 Oct 68

Loop no. 3(Al/SS)	Housing: 8" ID Aluminum
	Element: Filters Inc, I 4208 Lot 465
	Canister: Dol type 1

Procedure no. 13-A		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Coarse AC Dust		Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, fresh
Date blended with additives: 14 Oct 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Du Pont RP-2, Lot 333

Test duration, min	44	Calculated dirt loading, g	166
Fuel throughput, gal	894	Actual element weight gain, g	164
Average rate, gpm	20.3		

Time	0 min	End Test
Meter reading, gal	311	1205
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Pre-Test
WSIM, distilled water	48
IFT, distilled water, dyn/cm	27.4

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.1
pH	7.3
ST, dyn/cm	72.3

TABLE 100. SINGLE-ELEMENT LOOP TEST NO. 243 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	1.6	0	0			80
5	1.6	0	1	0.27	0-1	80
10	1.9	0	1			80
15	2.4	0	1			80
20	4.0	0	1			80
25	9.8	0	1			80
28	20.0	0	1	0.27	5-6	80
32	31.2	0	45	0.13	20+++	80
33	31.5	0	42	0.12	20+++	80
38	34.4	0	70		20+++	80
43	36.5	0	99		20+++	80
44	40.0	0	100+[a]	0.23	20+++	80

a. The initial time of the peak started at 20 psi + 20 sec.
The peak value of 100+ lasted from 20 psi + 12 min + 30 sec to the end of test.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-28	0.002	5.72
28-43	0.2	--
43-44	0.2	5.72

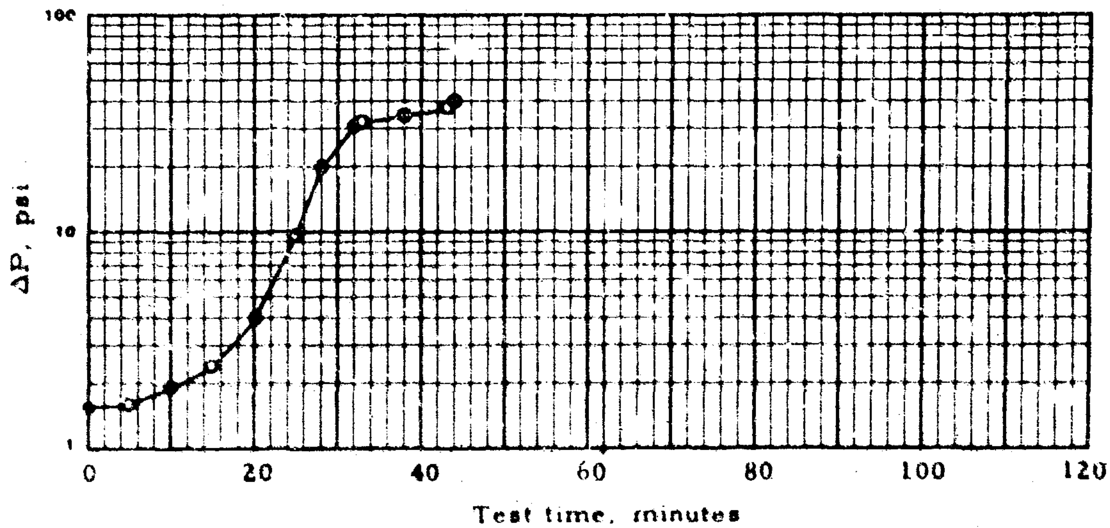


TABLE 101 . SINGLE-ELEMENT LOOP TEST NO. 244 Date: 15 Oct 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type I

Procedure no. 13-A		Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23 , fresh
Date blended with additives: 15 Oct 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Du Pont RP-2 , Lot 333

Test duration, min	54	Calculated dirt loading, g	263
Fuel throughput, gal	1085	Actual element weight gain, g	257
Average rate, gpm	20.1		

Time	0 min	End Test
Meter reading, gal	298	1383
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Pre-Test
WSIM, distilled water	36
IFT, distilled water, dyn/cm	26.8

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.3
ST, dyn/cm	72.2

TABLE 101. SINGLE-ELEMENT LOOP TEST NO. 244 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	1.6	0	0			80
5	1.7	0	0	0.21	14-15[a]	80
10	1.9	0	0		15-16	80
15	2.0	0	0			80
20	2.3	0	0			80
25	2.6	0	0			80
30	3.3	0	0			80
35	4.4	0	0			80
40	7.4	0	0			80
42	---	0	0		3-4	80
45	16.4	0	0			80
46	20.0	0	0	0.32	12-13	80
51	35.0	0	0	0.13	6-7	80
54	40.0	0	0	0.10	19-20	80

a. AEL--Fine distribution; irregular pattern.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-46	0.002	5.72
	46-54	0.2	--

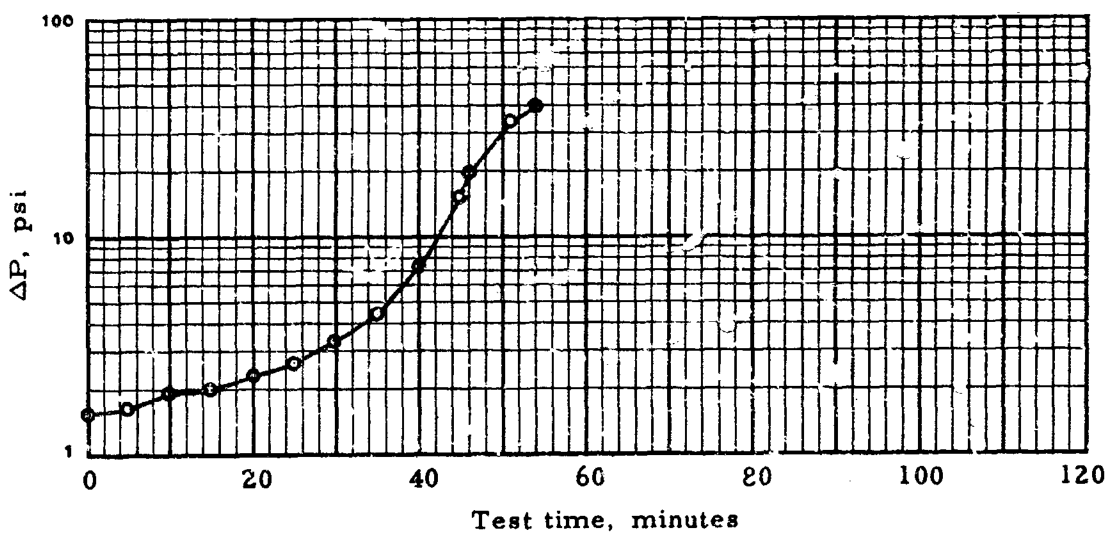


TABLE 102 . SINGLE-ELEMENT LOOP TEST NO. 245 Date: 16 Oct 68

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I 4208 Lot 465
Canister: DoD type I

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23 , fresh
Date blended with additives: 16 Oct 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Du Pont RP-2 , Lot 333

Test duration, min	50
Fuel throughput, gal	975
Average rate, gpm	19.5

Calculated dirt loading, g	200
Actual element weight gain, g	218

Time	0 min	End Test
Meter reading, gal	305	1280
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Pre-Test
WSIM, distilled water	40
IFT, distilled water, dyn/cm	27.0

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.3
ST, dyn/cm	72.3

TABLE 102. SINGLE-ELEMENT LOOP TEST NO. 245 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	1.5	0	0			80
5	1.5	0	0	0.19	4-5[a]	80
10	1.5	0	0			80
15	1.9	0	0			80
20	2.4	0	0			80
25	3.8	0	0			80
30	11.6	0	0			80
33	20.0	0	0	0.21	7-8	80
38	31.2	0	1	0.08	16-17	80
43	34.0	0	1		18-19	80
48	35.9	0	1		16-17	80
50	40.0	0	1	0.10	11-12	80

a. AEL--hard to read; fine dispersion.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-33	0.002	5.72
	33-48	0.2	--
	48-50	0.2	5.72

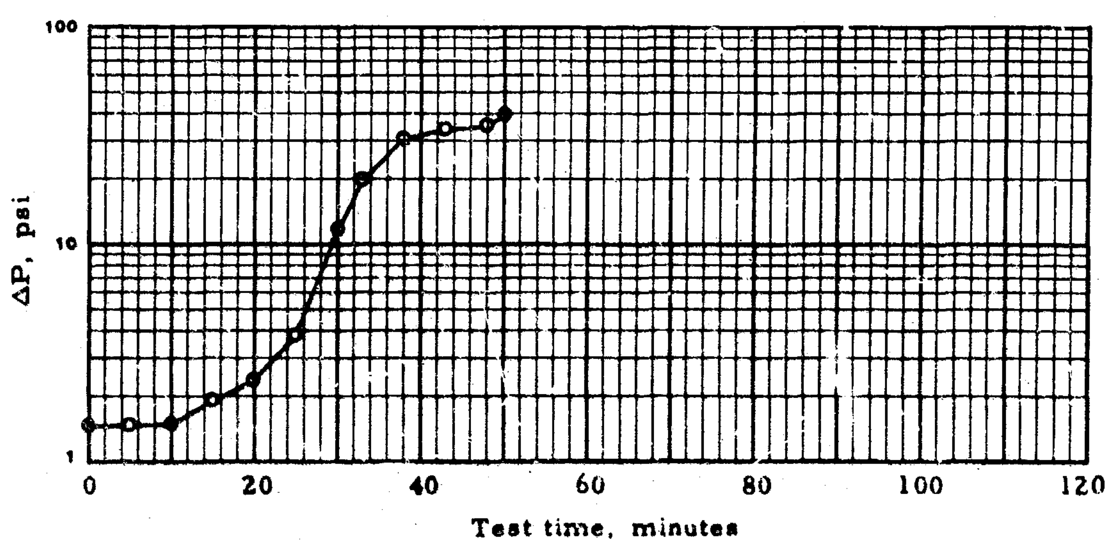


TABLE 103. SINGLE-ELEMENT LOOP TEST NO. 246 Date: 18 Oct 68

Loop no. 3 (Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 13-A	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23 , fresh
Date blended with additives: 18 Oct 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Du Pont RP-2 , Lot 333

Test duration, min	61	Calculated dirt loading, g	269
Fuel throughput, gal	1232	Actual element weight gain, g	259
Average rate, gpm	20.2		

Time	0 min	End Test
Meter reading, gal	299	1531
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Pre-Test
WSIM, distilled water	41
IFT, distilled water, dyn/cm	27.4

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.2
pH	7.4
ST, dyn/cm	72.1

TABLE 103. SINGLE-ELEMENT LOOP TEST NO. 246 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	1.8	0	0			80
5	2.0	0	0	0.26	2-3	80
10	2.0	0	0			80
15	2.0	0	0			80
20	2.3	0	0			80
25	2.7	0	0			30
30	3.5	0	0			80
35	5.0	0	0			80
40	8.5	0	0			80
45	16.1	0	0			80
47	20.0	0	0	0.28	7-8	80
52	31.3	0	1	0.15	18-19	80
57	35.2	0	1		16-17	80
61	40.0	0	0	0.06	17-18	80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-47	0.002	5.72
	47-61	0.2	--

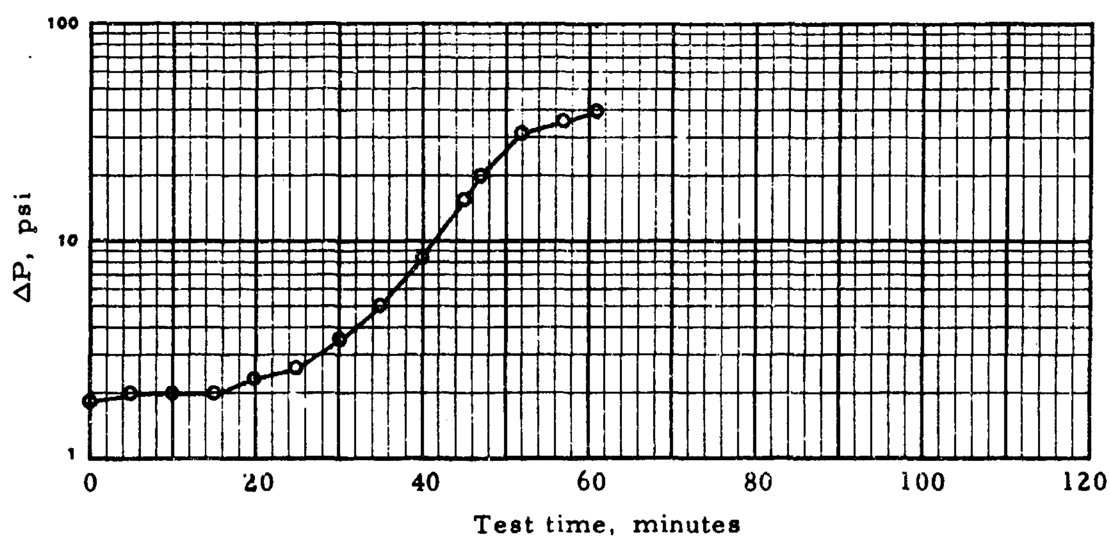


TABLE 104. SINGLE-ELEMENT LOOP TEST NO. 247 Date: 21 Oct 68

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I 4208 Lot 465
Canister: DoD type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, fresh, clay treated
Date blended with additives: 21 Oct 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Du Pont RP-2, Lot 333

Test duration, min	49
Fuel throughput, gal	978
Average rate, gpm	20.0

Calculated dirt loading, g	194
Actual element weight gain, g	193

Time	0 min	End Test
Meter reading, gal	305	1283
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Pre-Test
WSIM, distilled water	57
IFT, distilled water, dyn/cm	26.9

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.2
pH	7.6
ST, dyn/cm	72.0

TABLE 104. SINGLE-ELEMENT LOOP TEST NO. 247 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	1.7	0	0			80
5	2.0	0	0	0.19	1-2	80
10	2.0	0	0			80
15	2.4	0	0			80
20	3.0	0	0			80
25	4.9	0	0			80
30	11.5	0	0			80
33	20.0	0	0	0.12	4-5	80
38	30.0	0	0	0.06	11-12	80
43	32.5	0	0		12-13	80
48	34.4	0	0		18-19	80
49	40.0	0	0	0.08	18-19	80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-33	0.002	5.72
33-48	0.2	--
48-49	0.2	5.72

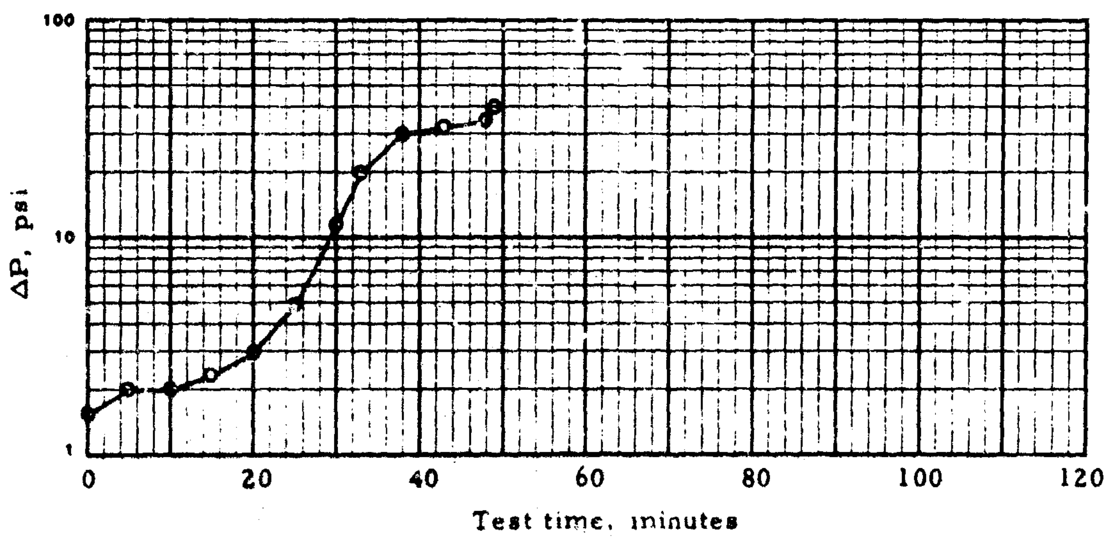


TABLE 105. SINGLE-ELEMENT LOOP TEST NO. 248 Date: 14 Nov 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 13-A	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, fresh, clay treated
Date blended with additives: 14 Nov 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Tolad 244, Lot 47-12

Test duration, min	26	Calculated dirt loading, g	137
Fuel throughput, gal	522	Actual element weight gain, g	126
Average rate, gpm	20.9		

Time	0 min	End Test
Meter reading, gal	309	831
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	32	37
IFT, distilled water, dyn/cm	45.1	27.9	27.5

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.10
pH	7.4
ST, dyn/cm	72.2

TABLE 105. SINGLE-ELEMENT LOOP TEST NO. 248 (Cont'd)

Time, min	ΔP, psi	Totamitor		Effluent, mg/liter		Influent fuel temperature, °F
		Infl	Effl	Solids	Free water	
0	2.5	0	0			80
5	2.5	0	0	0.04	1-2	80
15	3.3	0	0			80
20	10.0	0	0			81
23	20.0	0	0	0.16	1-2	81
25	40.0	0	0	0.16	19-20	81

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-23	0.002	5.72
	23-25	0.2	--

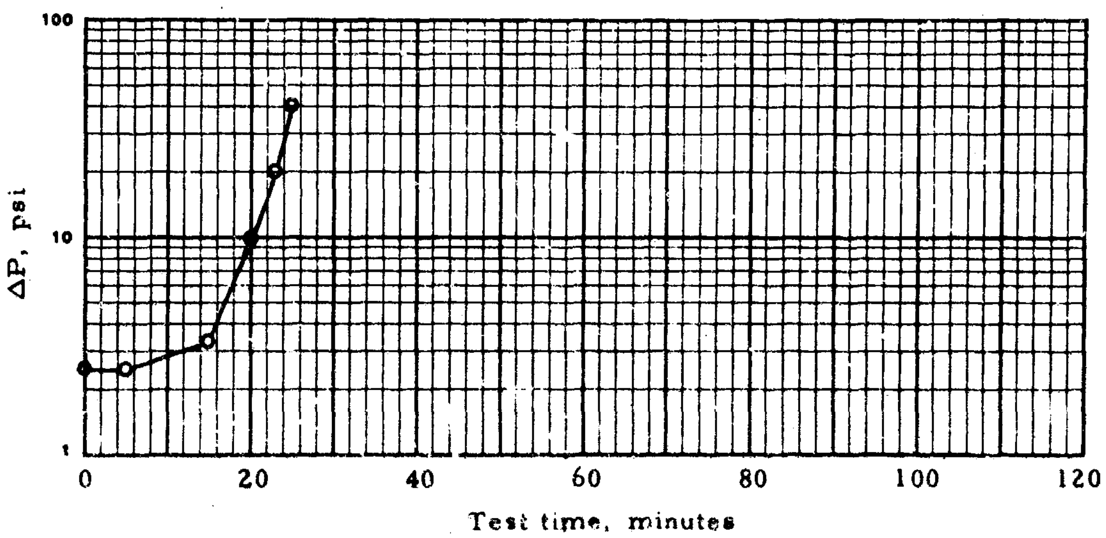


TABLE 106. SINGLE-ELEMENT LOOP TEST NO. 249 Date: 18 Nov 68

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I 4208 Lot 465
Canister: Dod type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min form 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23 , reused, clay treated
Date blended with additives: 18 Nov 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Tolad 244 , Lot 47-12

Test duration, min 28
Fuel throughput, gal 568
Average rate, gpm 20.3

Calculated dirt loading, g 132
Actual element weight gain, g 126

Time	0 min	End-Test
Meter reading, gal	309	877
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	41	32
IFT, distilled water, dyn/cm	44.0	28.8	28.0

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.30
pH	7.6
ST, dyn/cm	71.8

TABLE 106. SINGLE-ELEMENT LOOP TEST NO. 249 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.2	0	0			80
5	3.7	0	1	0.15	3-4	80
10	4.1	0	1			80
15	4.9	0	1			80
20	10.2	0	1			80
23	20.0	0	1	0.12	20	80
24	25.2	0	4			80
25	29.6	0	6			80
26	33.2	0	5			80
28	40.0	0	12	0.30	20+	80
29	45.0	0	23			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-23	0.002	5.72
23-28	0.2	--

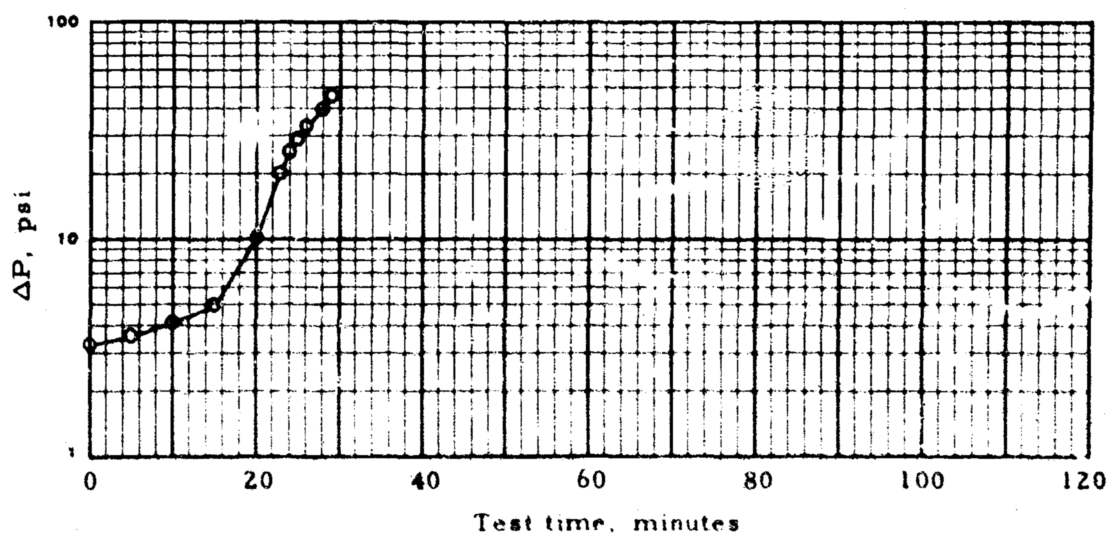


TABLE 107. SINGLE-ELEMENT LOOP TEST NO. 2.0 Date: 20 Nov 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1
Procedure no. 13-A		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Coarse AC Dust		Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, reused, clay treated

Date blended with additives: 20 Nov 68

Anti-icing additive 0.15 vol %, Dow, Lot 0226816

Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541, Lot 24794

Test duration, min	25	Calculated dirt loading, g	137
Fuel throughput, gal	506	Actual element weight gain, g	118
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	317	823
Screen ΔP, psi	4	4
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	58	60
IFT, distilled water, dyn/cm	44.2	28.9	29.3

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	---
ST, dyn/cm	73.3

TABLE 107. SINGLE-ELEMENT LOOP TEST NO. 250 (Cont'd)

Time, min	ΔP, psi	Rotamitor Infl	Rotamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	2.4	0	0			80
5	2.4	0	2	0.50	1-2[a]	80
10	2.6	0	2			80
15	3.4	0	2			80
20	8.3	0	1			80
23	20	0	14	0.63	8-9	80
25	40	0		0.64	20+++	80
27	50	0				80

a. Air bubbles were present in the sample. The water was finely dispersed on the AEL pad.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-23	0.002	5.72
	23-25	0.2	--

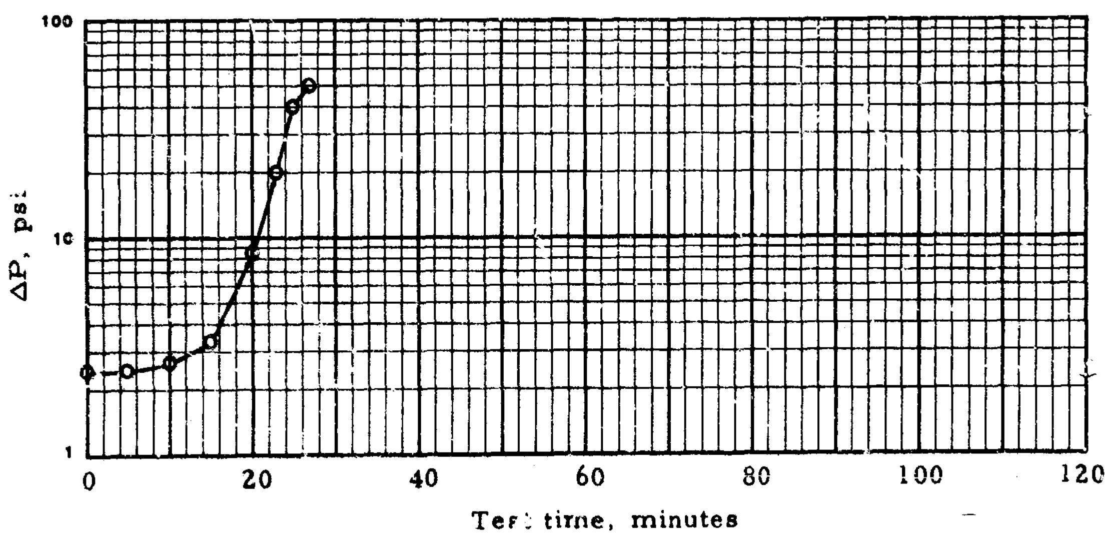


TABLE 108. SINGLE-ELEMENT LOOP TEST NO. 251 Date: 21 Nov 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 13-A		Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23 , reused, clay treated

Date blended with additives: 21 Nov 68

Anti-icing additive 0.15 vol %, Dow, Lot 0226816

Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	33	Calculated dirt loading, g	183
Fuel throughput, gal	660	Actual element weight gain, g	173
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	960
Screen ΔP, psi	4	4
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	98	47	58
IFT, distilled water, dyn/cm	39.8	28.3	27.6

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	---
ST, dyn/cm	72.9

TABLE 108. SINGLE-ELEMENT LOOP TEST NO. 251 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	2.4	0	0			80
5	2.5	0	3	0.78	2-3	80
10	2.6	0	2			80
15	3.3	0	2			80
20	4.5	0	2			80
25	7.1	0	1			80
30	14.8	0	1			80
32	20.0	0	1	1.46	13-14	80
33	40.0	0	29	0.73	20+++	80
35	49.2	0	85			80
38	44.5	0	5			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-32	0.002	5.72
	32-33	0.2	--

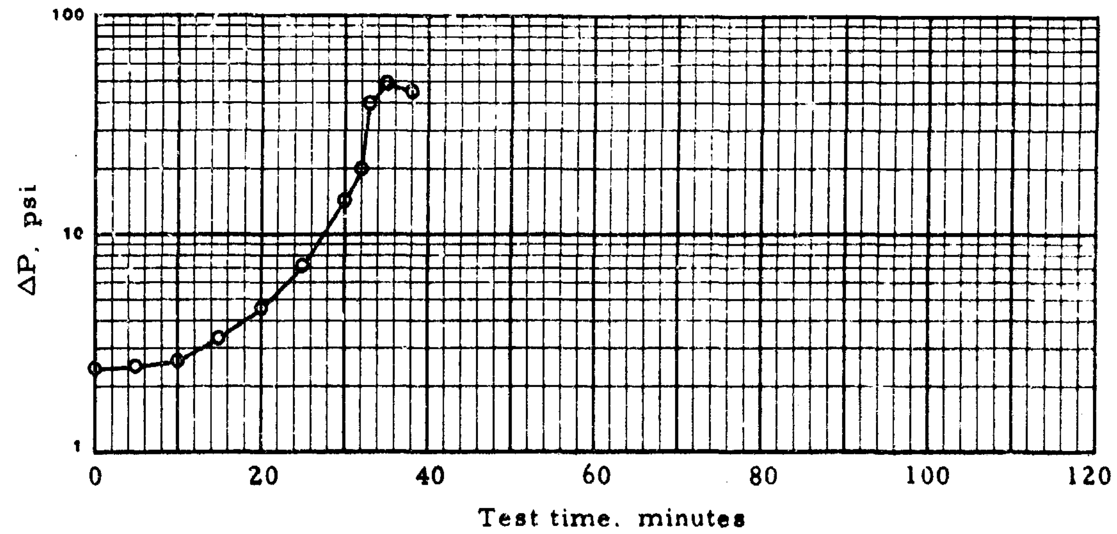


TABLE 109. SINGLE-ELEMENT LOOP TEST NO. 252 Date: 25 Nov 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 13-A	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, reused, clay treated

Date blended with additives:

Anti-icing additive	0.15	vol %, Dow, Lot 0226816	
Corrosion inhibitor	20	lb/Mbbl, Lubrizol 541	, Lot 24794

Test duration, min	35	Calculated dirt loading, g	183
Fuel throughput, gal	690	Actual element weight gain, g	182
Average rate, gpm	20.3		

Time	0 min	End Test
Meter reading, gal	300	990
Screen ΔP, psi	4	4
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	98	51	61
IFT, distilled water, dyn/cm	41.8	30.4	30.6

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	2.4
pH	7.7
ST, dyn/cm	73.7

TABLE 109. SINGLE-ELEMENT LOOP TEST NO. 252 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	1.9	0	0			80
5	2.0	0	2[a]	0.53	2-3	80
10	2.1	0	2			80
15	2.5	0	2			80
20	3.4	0	2			80
25	5.6	0	2			80
30	13.7	0	2			80
32	20.0	0	2	1.41	10-11	80
34	40.0	0	56	1.68	20+++	80
35	45.5	0	100+			80

a. The ΔP read 2 from 5 min to 20 psi. The initial time of the peak started at 20 psi + 1 min and 30 sec or 40 psi. At 20 psi + 3 min a peak of 100+ was reached.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-32	0.002	5.72
	32-35	0.2	--

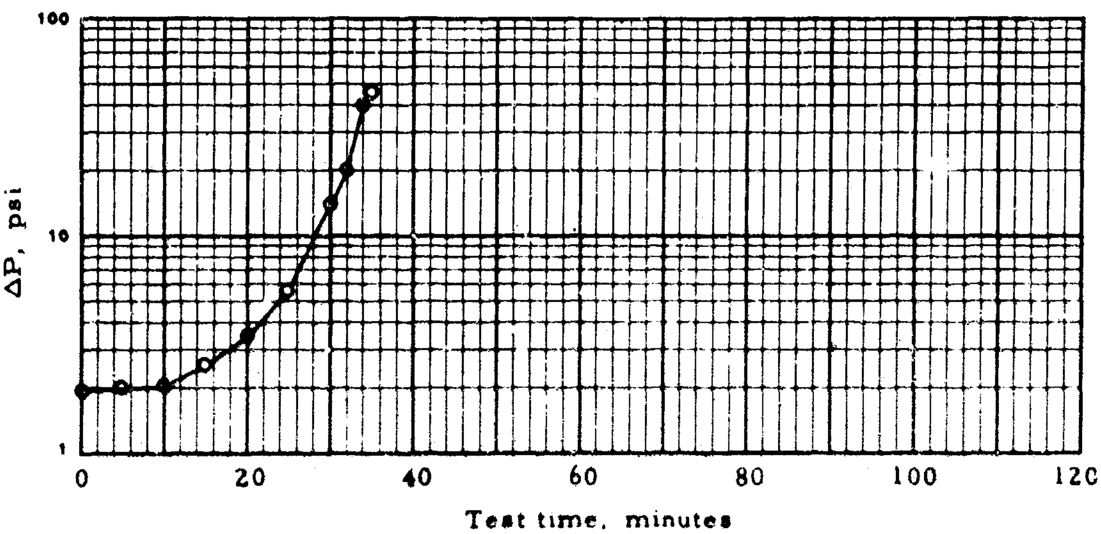


TABLE 110. SINGLE-ELEMENT LOOP TEST NO. 253 Date: 26 Nov 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 13-A	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23 , reused, clay treated
Date blended with additives: 26 Nov 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Unicor-M , Lot 0020

Test duration, min	27	Calculated dirt loading, g	143
Fuel throughput, gal	541	Actual element weight gain, g	150
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	841
Screen ΔP, psi	4	4
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	95	33	34
IFT, distilled water, dyn/cm	39.8	26.8	26.3

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.2
pH	7.3
ST, dyn/cm	67.6

TABLE 110. SINGLE-ELEMENT LOOP TEST NO. 253 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	2.1	0	0			80
5	2.4	0	0	0.09	0-1	80
10	2.4	0	0			80
15	3.1	0	0			80
20	5.7	0	0			80
25	20.0	0	0	0.11	2-3	80
27	40.0	0	1[a]	0.14	8-9	80
28	44.0	0	1			80
29	41.5	0	0			80
31	38.5	0	1			80

a. The initial time of the peak started at 20 psi + 30 sec. The peak value occurred at 20 psi + 2 min and 10 sec.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-25	0.002	5.72
	25-27	0.2	--

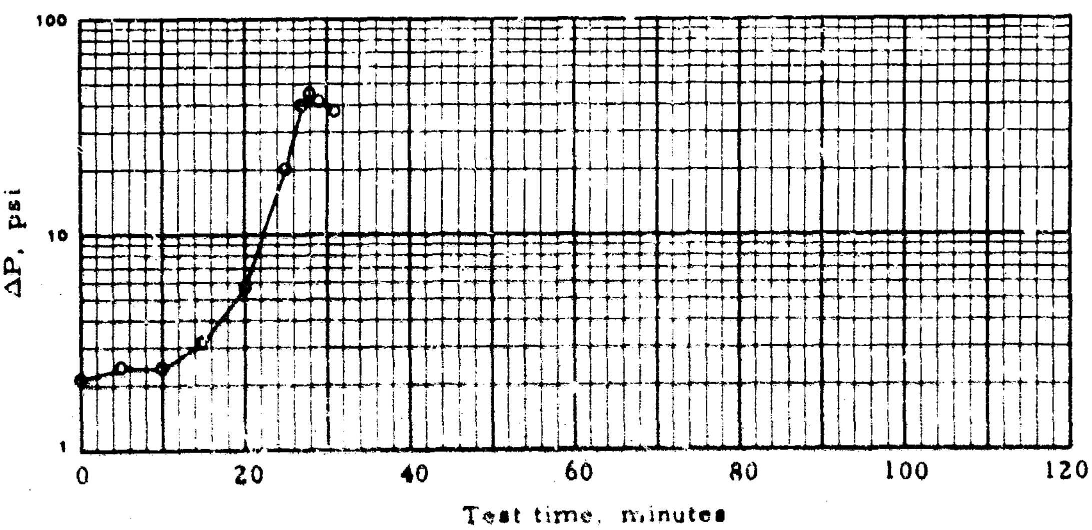


TABLE 111. SINGLE-ELEMENT LOOP TEST NO. 254 Date: 27 Nov 68

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I 4208 Lot 465
Canister: DoD type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, reused, clay treated
Date blended with additives: 27 Nov 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Unicor-M, Lot 0020

Test duration, min 58
Fuel throughput, gal 1157
Average rate, gpm 19.9

Calculated dirt loading, g 246
Actual element weight gain, g 250

Time	0 min	End Test
Meter reading, gal	300	1457
Screen ΔP, psi	4	4
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	35	32
IFT, distilled water, dyn/cm	38.0	21.1	27.3

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.4
pH	7.1
ST, dyn/cm	71.1

TABLE 111. SINGLE-ELEMENT LOOP TEST NO. 254 (Cont'd)

Time, min	ΔP, psi	Totamitor		Effluent, mg/liter		Influent fuel temperature, °F
		Infl	Effl	Solids	Free water	
0	2.1	0	0			80
5	2.3	0	0	0.06	0-1	80
10	2.4	0	0			80
15	2.6	0	0			80
20	3.2	0	0			80
25	5.2	0	0			80
30	7.5	0	0			80
35	10.8	0	0			80
40	16.0	0	0			80
42	20.0	0	0	0.23	6-7	80
47	32.5	0	59[a]	0.44	20+++	80
52	34.2	0	72		20+++	80
57	36.2	0	73		20+++	80
58	40.0	0	68	0.43	20+++	80
59	45.5	0	68			80
61	35.0	0	68			80

a. The initial time of the peak started at 20 psi + 15 sec and a peak of 85 was reached at 20 psi + 15 min.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-42	0.002	5.72
	42-58	0.2	--

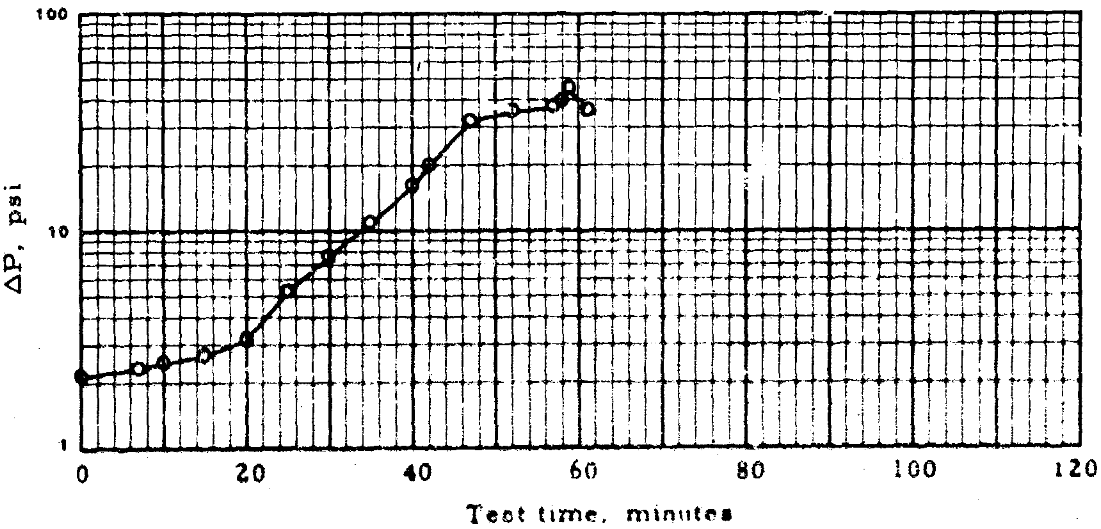


TABLE 112. SINGLE-ELEMENT LOOP TEST NO. 255 Date: 2 Dec 68

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I 4208 Lot 465
Canister: DoD type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 23, reused, clay treated
Date blended with additives: 2 Dec 68
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Unicor M, Lot 0020

Test duration, min	27
Fuel throughput, gal	541
Average rate, gpm	20.0

Calculated dirt loading, g	132
Actual element weight gain, g	129

Time	0 min	End Test
Meter reading, gal	300	841
Screen ΔP, psi	4	4
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	36	41
IFT, distilled water, dyn/cm	39.6	23.2	--

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.6
ST, dyn/cm	71.1

TABLE 112. SINGLE-ELEMENT LOOP TEST NO. 255 (Cont'd)

Time, min	ΔP, psi	Totamitor		Effluent, mg/liter		Influent fuel temperature, °F
		Infl	Effl	Solids	Free water	
0	2.1	0	0			80
5	2.2	0	0	0.03	0-1	80
10	2.3	0	0			80
15	3.7	0	0			80
20	12.0	0	0			80
23	20.0	0	0[a]	0.07	1-2	80
27	40.0	0	2	0.04	16-17	80
28	42.5					80
29	39.2					80
31	36.6					80

a. The initial time of the peak started at 20 psi + 40 sec. The peak was reached at 20 psi + 4 min and 10 sec.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-23	0.002	5.72
23-27	0.2	--

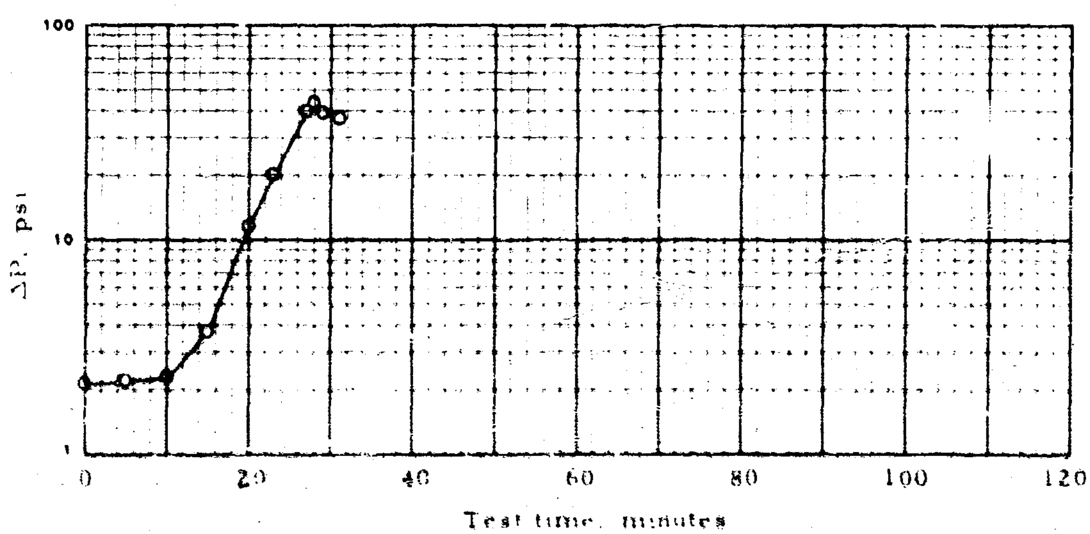


TABLE 113. SINGLE-ELEMENT LOOP TEST NO. 256 Date: 6 Dec 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 8901-B (inhib fuel test)		Fuel flow, gpm	40
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Coarse AC Dust		Fuel inlet pressure, psi	100

Water injection schedule: 0.4 gpm water from 0 min to end of test.

Solids injection schedule: 0 g/min coarse AC Dust from 0 to 60 min, then 2.86 g/min to end of test.

Test fuel JP-5 batch no. 23 , fresh, clay treated
Date blended with additives:
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH 4-006

Test duration, min	96	Calculated dirt loading, g	103
Fuel throughput, gal	3839	Actual element weight gain, g	112
Average rate, gpm	40.0		

Time	0 min	End Test
Meter reading, gal	0	38.39
Screen ΔP, psi	8	8
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	0 Min	Post-Test
WSIM, distilled water	100	87	96
IFT, distilled water, dyn/cm	41.2	36.1 33.9	38.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	7.4
ST, dyn/cm	71.5

TABLE 113. SINGLE-ELEMENT LOOP TEST NO. 256 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
		Peak 25 at 63 min				
0	0	0	0			80
5	8.5	0	4	0.10	2-3	80
10	9.4	0	4	0.04	4-5	80
15	9.8	0	4			80
20	10.5	0	4	Neg	3-4	80
25	10.9	0	4			80
30	11.6	0	5	Neg	8-9	80
35	12.4	0	7			80
40	12.9	0	10	0.11	17-18	80
45	13.3	0	11			80
50	13.9	0	15	0.10	20+	80
55	14.3	0	16			80
60	15.0	0	23	0.14	20+	80
65	13.8	0	7			80
70	14.5	0	6	Neg	11-12	80
75	15.3	0	5			80
80	17.5	0	5	Neg	12-13	80
85	20.6	0	8			80
90	27.5	0	8	Neg	16-17	80
95	37.5	0	14			80
96	40.0	0	15	Neg	20+	80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-60	.4	--
60-96	.4	2.86

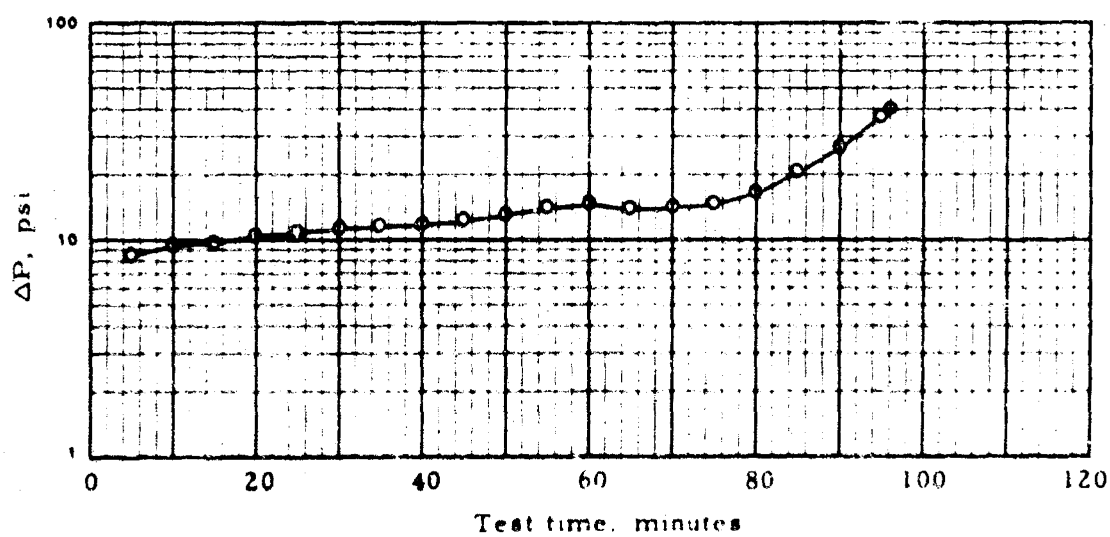


TABLE 114. SINGLE-ELEMENT LOOP TEST NO. 257 Date: 19 Dec 68

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 8901-B (inhib fuel test)
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	30
Fuel inlet temperature °F	80
Fuel inlet pressure, psi	100

Water injection schedule: 0.3 gpm water from 0 min to end of test.

Solids injection schedule. 0 g/min coarse AC Dust from 0 to 60 min, then 2.86 g/min to end of test.

Test fuel JP-5 batch no. 23, fresh, clay treated
Date blended with additives:
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH 04-006

Test duration, min	134	Calculated dirt loading, g	212
Fuel throughput, gal	4005	Actual element weight gain, g	216
Average rate, gpm	29.9		

Time	0 min	End Test
Meter reading, gal	0	4005
Screen ΔP, psi	4	4
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	0 Min	Post-Test
WSIM, distilled water	99	77	97
IFT, distilled water, dyn/cm	45.8	40.9	44.3
IFT, injection H_2O, dyn/cm	42.8	22.8	28.2

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0
pH	7.6
ST, dyn/cm	70.0

TABLE 114. SINGLE-ELEMENT LOOP TEST NO. 257 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.2	0	0			80
5	5.6	0	2	0.06	0-1	80
10	6.5	0	4	0	0-1	80
15	6.6	0	4			81
20	7.1	0	4	0	0-1	80
25		0	4			80
30	7.9	0	2	Neg	0-1	80
35	8.2	0	2			80
40	8.5	0	2	0.11	0-1	80
45	8.7	0	2		2-3	80
50	8.9	0	2	0.03	0-1	80
55	9.0	0	2			80
60	9.5	0	2	0.04	0-1	80
65	8.5	0	1			80
70	9.5	0	1	0.11	0-1	80
75	9.6	0	1			80
80	10.5	0	1	0.01	0-1	80
85	11.0	0	1			80
90	12.0	0	4	Neg	12-13	80
95	13.0	0	1		1-2	80
100	14.3	0	1	Neg	0-1	80
105	15.4	0	2			80
110	17.4	0	2	0.03	0-1	80
115	19.2	0	2			81
117	20.0	0	2			81
120	21.8	0	2		1-2	81
125	24.8	0	2-3			81
130	28.8	0	3	0.04	1-2	81
134	40.0	0	9	0	8-9	81

Schedule:

Minutes	Water, gpm	Solids, g/min
0-60	0.3	--
60-134	0.3	2.86

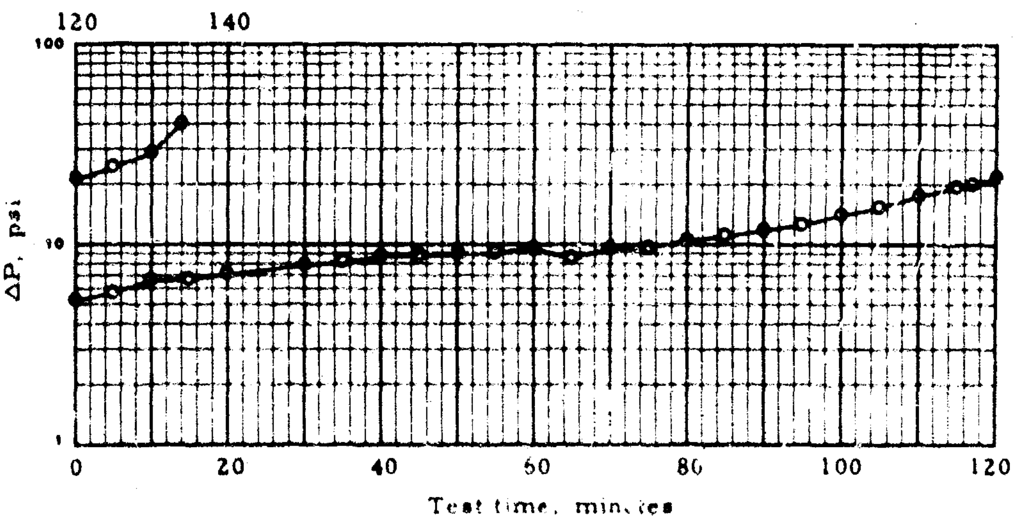


TABLE 115. SINGLE-ELEMENT LOOP TEST NO. 258A Date: 26 Dec 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 8901B (media migration)	Fuel flow, gpm	6 to 34.5
Water: ----	Fuel inlet temperature, °F	80
Solids: ----	Fuel inlet pressure, psi	10 to 70

Water injection schedule: No water injected.

Solids injection schedule: No solids injected.

Test fuel JP-5 batch no. 23, fresh
Date blended with additives: ----
Anti-icing additive ---- vol %, Dow, Lot ----
Corrosion inhibitor ---- lb/Mbbl, ---- , Lot ----

Test duration, min	60	Calculated dirt loading, g	----
Fuel throughput, gal	1259	Actual element weight gain, g	----
Average rate, gpm	21.0		

Time	0 min	End Test
Meter reading, gal	0	1259
Screen ΔP, psi	1	3
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	0 min
WSIM, distilled water	75
IFT, distilled water, dyn/cm	42.8

Analyses on injection water:

	Post-Test
Time	0.06
Solids, mg/liter	----
pH	----
ST, dyn/cm	----

TABLE 115. SINGLE-ELEMENT LOOP TEST NO. 258A (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3	0	0		0	80
5	3.5	0	0	0.05	0	80
10	3	0	0	Neg	0	80
15	3	0	0		0	80
20	3	0	0	0.02	0	80
25	2.5	0	0			80
30	2.5	0	0	Neg	0	80
35	1	0	0			80
40	1	0	0	0.10	0	80
45	0.6	0	0			80
50	0.8	0	0	Neg	0	82
55	4	0	0			80
60	4	0	0	0.06	0	80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-60	--	--

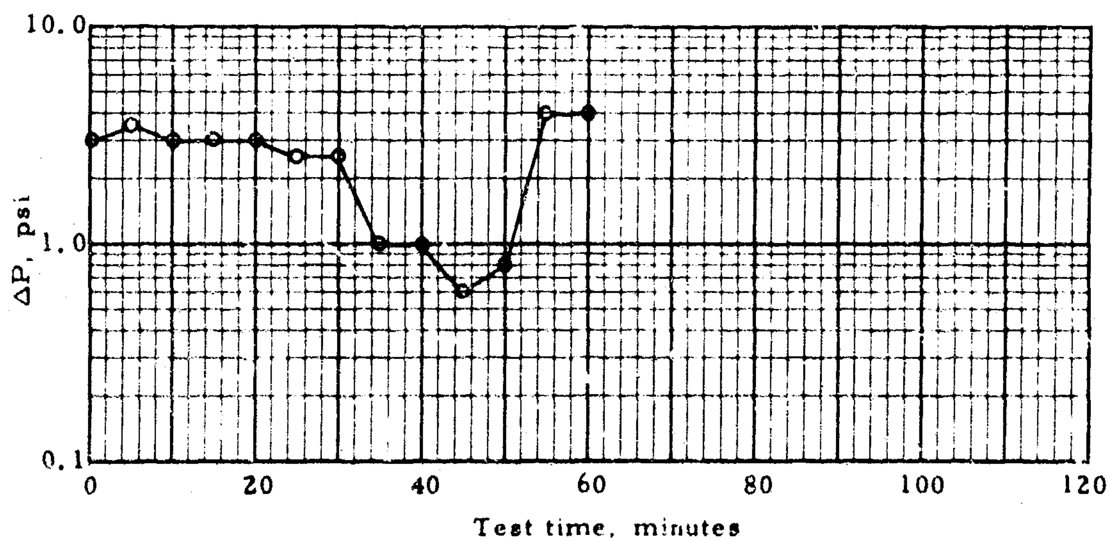


TABLE 116. SINGLE-ELEMENT LOOP TEST NO. 258B Date: 26 Dec 68

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 465
		Canister:	DoD type 1

Procedure no. 8901B (Dry Red Iron Oxide)		Fuel flow, gpm	30
Water:	----	Fuel inlet temperature, °F	80
Solids:	Red Iron Oxide	Fuel inlet pressure, psi	100

Water injection schedule: No water injected.

Solids injection schedule: 2.86 g/min from 0 min to end of test.

Test fuel JP-5 batch no. 23 , fresh
Date blended with additives: 26 Dec 68
Anti-icing additive ---- vol %, Dow, Lot ----
Corrosion inhibitor ---- lb/Mbbl, ---- , Lot ----

Test duration, min	115	Calculated dirt loading, g	329
Fuel throughput, gal	3424	Actual element weight gain, g	298
Average rate, gpm	29.8		

Time	0 min	End Test
Meter reading, gal	0	3424
Screen ΔP, psi	8	8
Cleanup ΔP, psi	2	1

Analyses on influent fuel:

Time	
WSIM, distilled water	
IFT, distilled water, dyn/cm	

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	6.86
pH	----
ST, dyn/cm	----

TABLE 116. SINGLE-ELEMENT LOOP TEST NO. 258B (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3	0	0			80
5	3	0	35	0.88	0	80
10	4	2	43	0.87	0	80
20	4	2	20	0.74	0	80
25	4	2	23	0.20		80
30	4.5	3	25	0.84	0	80
40	4	2	17	0.49	0	80
50	5.5	2	27	3.40	0	80
60	6.5	2	28	1.00	0	80
70	7.5	2	35	1.45	0	80
80	8.5	2	40	1.67	0	81
90	10	2	53	2.52	0	81
100	11	2	56	3.06	0	81
110	12			22.38	0	81
115	18	5	88	6.86	0	81

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-115	--	2.86

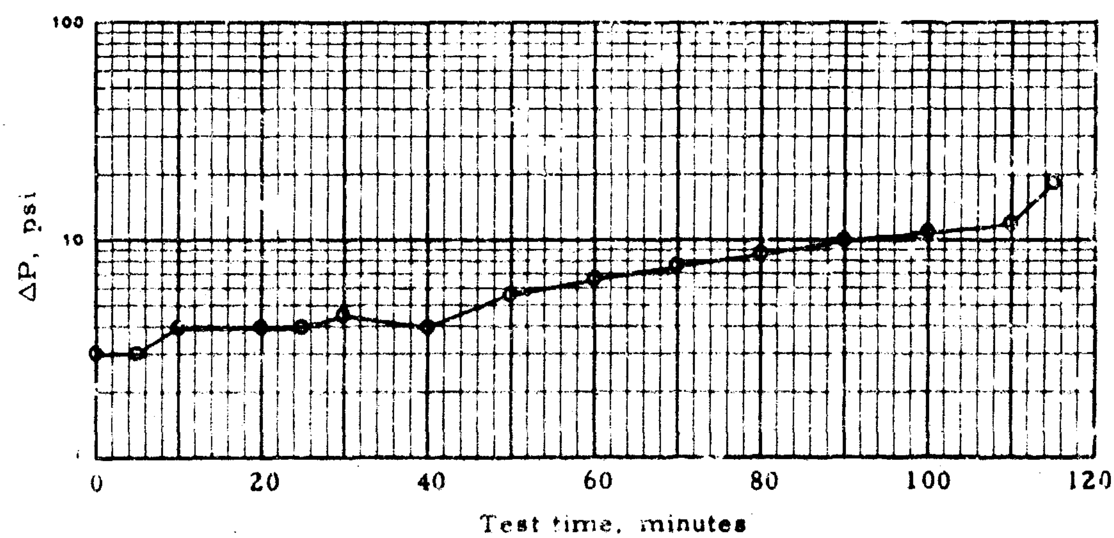


TABLE 117. SINGLE-ELEMENT LOOP TEST NO. 259A Date: 9 Jan 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 8901-B (media migration)		Fuel flow, gpm	6-34.5
Water:	None	Fuel inlet temperature, °F	80
Solids:	None	Fuel inlet pressure, psi	7-78

Water injection schedule: No water injected.

Solids injection schedule: No solids injected.

Test fuel JP-5 batch no. 24 , fresh, clay treated
Date blended with additives:
Anti-icing additive vol %, Dow, Lot
Corrosion inhibitor lb/Mbbl, , Lot

Test duration, min	60	Calculated dirt loading, g	
Fuel throughput, gal	1218	Actual element weight gain, g	
Average rate, gpm	20.3		

Time	0 min	End Test
Meter reading, gal	0	1218
Screen ΔP, psi	28	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	0 Min
WSIM, distilled water	100	96
IFT, distilled water, dyn/cm	45.8	46.2

Analyses on injection water:

Time
Solids, mg/liter
pH
ST, dyn/cm

TABLE 117. SINGLE-ELEMENT LOOP TEST NO. 259A (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.0	0	0			80
5	6.0	0	0	0.14	0	81
10	6.0	0	0	0.02	0	81
15	3.5	0	0			80
20	3.5	0	0	0.18		80
25	2.5	0	0			80
30	2.5	0	0	0.02		80
35	1.5	0	0			81
40	1.5	0	0	0.06		81
45	1.5	0	0			80
50	1.5			0.02		80
55	5.0	0	2			80
60	6.0	0	0	0.07		80

Schedule:	Minutes	Fuel flow, gpm	Solids, g/min
	0-10	30	
	10-20	24	
	20-30	18	
	30-40	12	
	40-50	6	
	50-60	34.5	

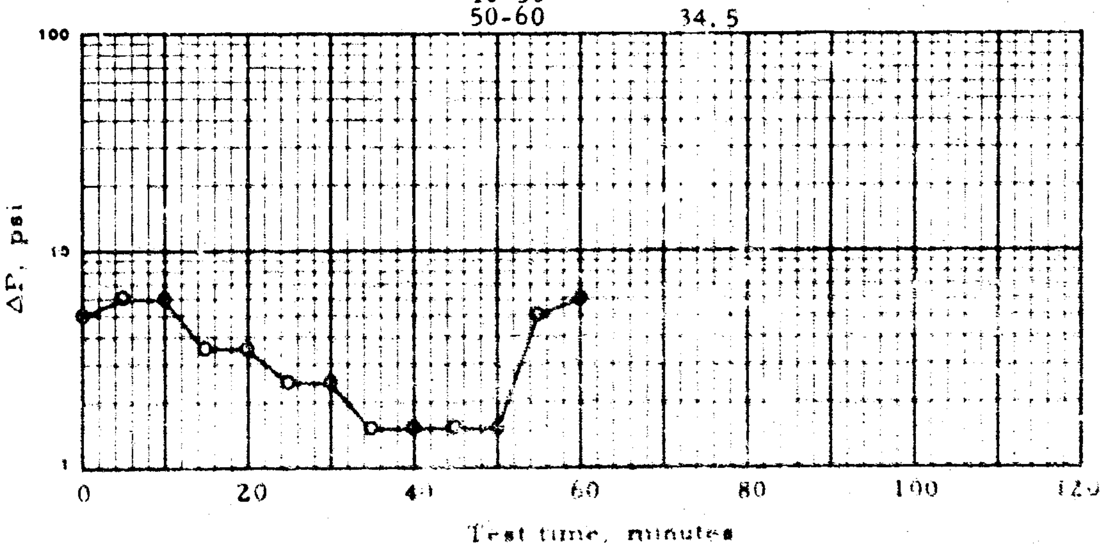


TABLE 118. SINGLE-ELEMENT LOOP TEST NO. 259B Date: 9 Jan 69

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I 4208 Lot 516[a]
Canister: DoD type 1

Procedure no. 8901-B (Dry Iron Oxide)
Water: None
Solids: Red Iron Oxide

Fuel flow, gpm 30
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70 & 100

Water injection schedule: No water injected.

Solids injection schedule: 2.86 g/min of Red Iron Oxide from 0 min to end of test.

Test fuel JP-5 batch no. 24, fresh, clay treated
Date blended with additives:
Anti-icing additive vol %, Dow, Lot
Corrosion inhibitor lb/Mbbl, , Lot

Test duration, min 106
Fuel throughput, gal 3118
Average rate, gpm 29.8

Calculated dirt loading, g 297
Actual element weight gain, g 275

Time	0 min	End Test
Meter reading, gal	1218	4336
Screen ΔP, psi	2	6
Cleanup ΔP, psi	0	0

Analyses on influent fuel:
- Time
- WSIM, distilled water
- IFT, distilled water, dyn/cm

Analyses on injection water:
- Time
- Solids, mg/liter
- pH
- ST, dyn/cm

a. Same element used in Test 259A.

TABLE 118. SINGLE-ELEMENT LOOP TEST NO. 259B (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	6	0	0	0.07		80
5	5	0	2	0.29		80
10	5	0	1	Neg		80
15	6	0	1			80
20	7	0	2	0.21		80
25	7	0	3			80
30	8	0	3	0.06		80
32	8[a]	0	3			80
35	9	0	2			80
40	10	0	2	0.19		80
45	11.5	0	2			80
50	13.5	0	3	0.13		80
55	16.5	0	3			80
60	20.0	0	2	0.06		80
65	23.0	0	2			80
70	26.0	0	2	0.15		80
75	27.0	0	2			80
80	35.5	0	2	Neg		80
85	40.0	0	2	0.22		80
90	44.0	0	2	0.22		80
100[b]	70.0	0	2	0.28		80
104	75.0	0	6			80
106	76.0	0	4			80

a. Fuel inlet pressure changed from 70 psi to 100 psi.
b. Sample pulled from 100 min to 104 min.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-104		2.86

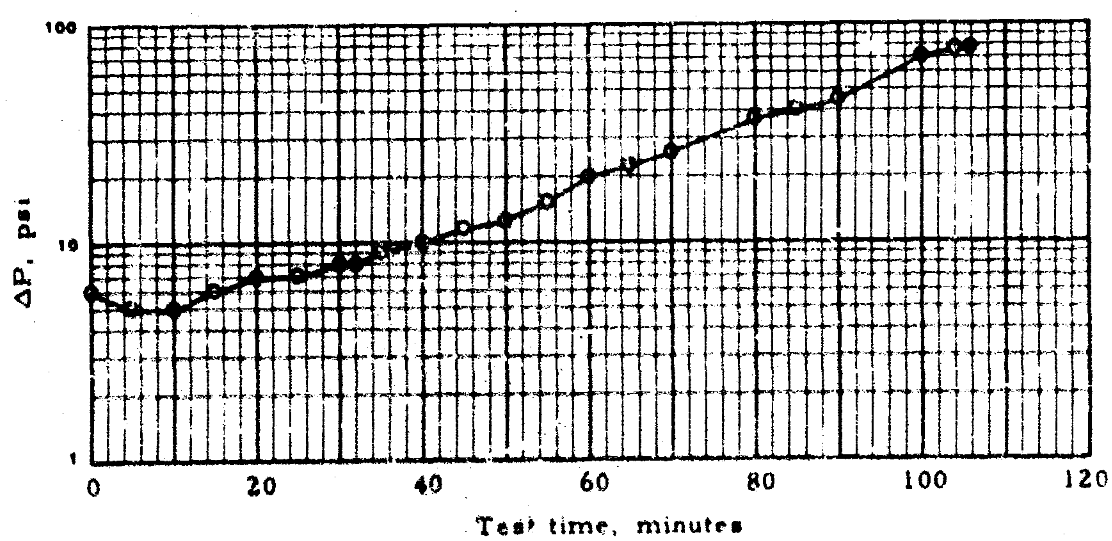


TABLE 119. SINGLE-ELEMENT LOOP TEST NO. 260A Date: 14 Jan 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 8901B (Water Removal)		Fuel flow, gpm	34.5 & 32.8
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	None	Fuel inlet pressure, psi	70

Water injection schedule: 0.17 gpm from 0 min to 60 min, then
1.32 gpm from 61 min to end of test (120 min).

Solids injection schedule: None

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives:
Anti-icing additive vol %, Dow, Lot
Corrosion inhibitor lb/Mbbl, , Lot

Test duration, min	120	Calculated dirt loading, g	
Fuel throughput, gal	4037	Actual element weight gain, g	
Average rate, gpm	34.5 for 1st hour - 32.8 for 2nd hour.		

Time	0 min	End Test
Meter reading, gal	0	4037
Screen ΔP, psi	5	5
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Treated
WSIM, distilled water	99
IFT, distilled water, dyn/cm	4[illegible].0

Analyses on injection water:

Time	Pre-Test
Solids, mg/liter	
pH	6.5
ST, dyn/cm	69.5

TABLE 119. SINGLE-ELEMENT LOOP TEST NO. 260A (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
5	5.0	0	0			80
10	6.0	0	0		0-1	80
15	6.0	0	0			80
20	6.0	0	0		0-1	80
25	6.0	0	0			80
30	6.0	0	0		1-2	80
35	6.0	0	0			80
40	6.0	0	0		0-1	80
45	6.0	0	0			80
50	6.0	0	0		0	80
55	6.0	0	0			80
60	6.0	0	0		1-2	80
65	7.0	0	0			80
70	7.0	0	0		2-3	80
80	8.0	0	0		1-2	80
90	9.0	0	0		2-3	80
100	9.0	0	0		2-3	80
105	9.0	0	0			80
110	9.0	0	0		4-5	80
120	9.0	0	0		3-4	80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-60	0.17	
	61-120	1.32	

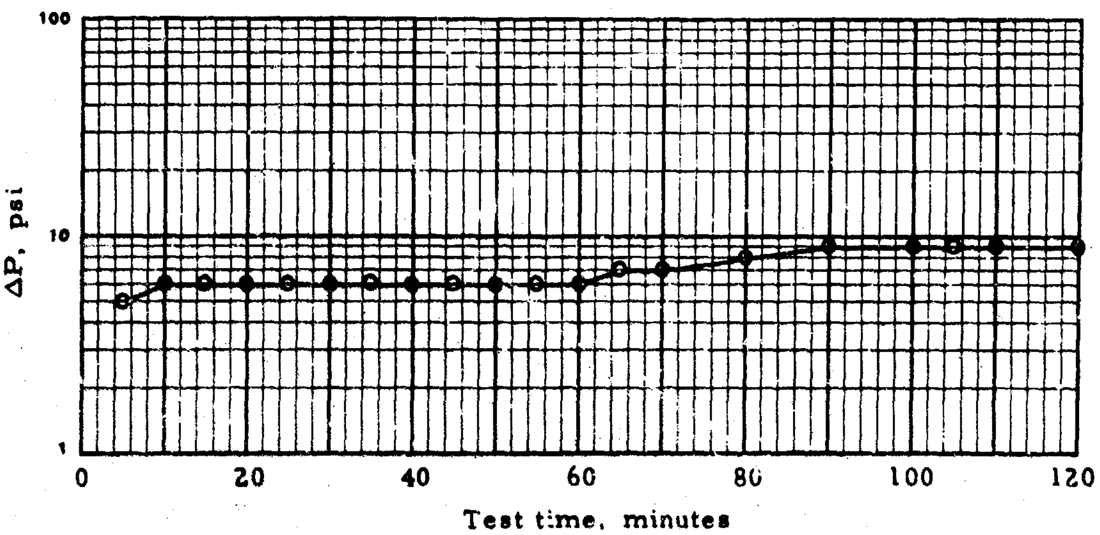


TABLE 120. SINGLE-ELEMENT LOOP TEST NO. 260B
Date: 14 January 1969

Loop no.	3(Al/SS)	**Housing:**	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516[a]
		Canister:	DoD Type I

Procedure no.	3901-B **(RIO and water)**	**Fuel flow, gpm**	30
Water:	Filtered Tap Water	**Fuel inlet temperature, °F**	80
Solids:	Red Iron Oxide	**Fuel inlet pressure, psi**	70

Water injection schedule: 0.9 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min Red Iron Oxide from 0 min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives:
Anti-icing additive **vol %, Dow, Lot**
Corrosion inhibitor **lb/Mbbl,** **, Lot**

Test duration, min	93	**Calculated dirt loading, g**	266
Fuel throughput, gal	2775	**Actual element weight gain, g**	199
Average rate, gpm	29.8		

Time	0 Min	End Test
Meter reading, gal	0	2775
Screen ΔP, psi	5	6
Cleanup ΔP, psi	0	0

Analyses on influent fuel:
Time
WSIM, distilled water
IFT, distilled water, dyn/cm

Analyses on injection water:

Time	Post Test
Solids, mg/liter	
pH	7.7
ST, dyn/cm	72.7

a. Same element used in Test 260-A.

TABLE 120. SINGLE-ELEMENT LOOP TEST NO. 260B (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	9.0	0	0			80
5	9.0	1	0	0	1-2	80
10	10.0	0	0	0.08	1-2	80
20	11.0	0	0	0.18	1-2	80
30	12.0	0	0	0.09	0-1	80
40	14.0	0	0	0	0-1	80
50	16.0	0	0	0.05	0-1	80
60	18.5	0	0	0.58	0-1	80
70	25.0	0	1	Neg	2-3	80
80	32.0	0	1	Neg	2-3	80
85[a]	35.0	0	1			80
92	40.0	0	1	Neg	2-3	80
98	35.0					80

a. At 85 min, sump water began showing signs of collecting RIO at a fast rate. Analysis of the sump water indicated 38.23 mg/liter of RIO present.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-92	0.9	2.86

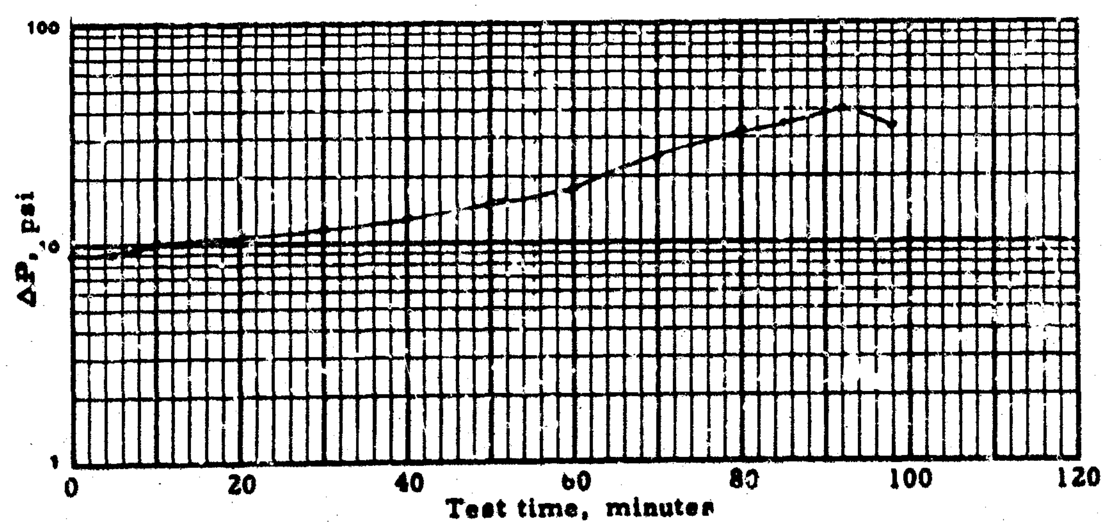


TABLE 121. SINGLE-ELEMENT LOOP TEST NO. 261
Date: 11 February 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Fram Lot 14, DoD type
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, fresh, clay treated
Date blended with additives: 11 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH04-006

Test duration, min 55
Fuel throughput, gal 1105
Average rate, gpm 20.1

Calculated dirt loading, g 229
Actual element weight gain, g 185

Time	0 Min	End Test
Meter reading, gal	300	1405
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	98	76	69
IFT, distilled water, dyn/cm	47.7	38.3	42.4

Analyses on injection water:

Time	Post Test
Solids, mg/liter	.52
pH	---
ST, dyn/cm	72.2

TABLE 121. SINGLE-ELEMENT LOOP TEST NO. 261 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.9	0	0			80
5	5.3	0	0	0.14	1-2	80
10	5.9	0	0			80
15	7.5	0	0			80
20	9.5	0	0			80
25	11.9	0	0			80
30	14.3	0	0			80
35	16.5	0	0			80
39	20.0	0	0*	0.12	8-9	80
44	30.0	0	1	0.10	20+	80
49	32.1	0	2		20+++	80
54	35.7	0	4		20+++	80
55	40.0	0	4	0.14	20+++	80
57	44.8	0	0			80
60	34.2	0	0			80

* A peak of 5 was reached 30 sec before 40 psi.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-39	0.002	5.72
39-54	0.2	----
54-55	0.2	5.72

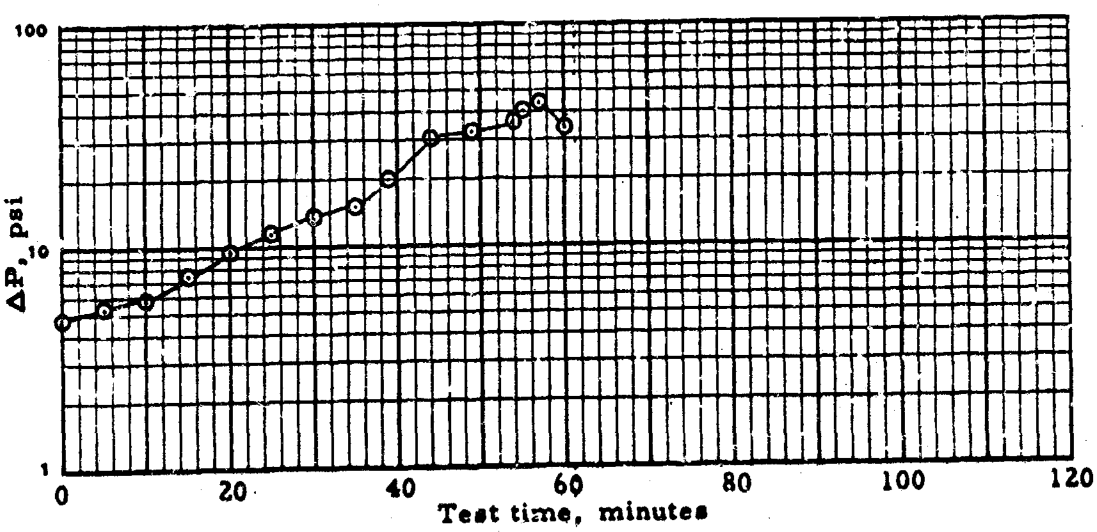


TABLE 122. SINGLE-ELEMENT LOOP TEST NO. 262
Date: 12 February 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bendix, Part No. 045800-04
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 12 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH04-006

Test duration, min 68
Fuel throughput, gal 1368
Average rate, gpm 20.1

Calculated dirt loading, g 303
Actual element weight gain, g 269

Time	0 min	End Test
Meter reading, gal	300	1668
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	98	78	68
IFT, distilled water, dyn/cm	49.1	37.7	39.1

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.31
pH	8.6*
ST, dyn/cm	70.5

* Another sample pulled on 13 Feb 69, pH-7.4

TABLE 122. SINGLE-ELEMENT LOOP TEST NO. 262 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	0	0			80
5	4.3	0	0	0.02	7-8	80
10	4.8	0	0			80
15	6.0	0	0		7-8	80
20	7.1	0	0			80
25	8.3	0	0			80
30	9.9	0	0			80
35	11.1	0	0			80
40	13.9	0	0			80
45	15.2	0	0			80
50	18.2	0	0			80
52	20.0	0	0	0.06	14-15	80
57	29.5	0	0	0.09	10-11	80
62	31.2	0	0		16-17	80
67	33.1	0	1		19-20	80
68	40.0	0	1	0.05	17-18	80
70	43.0	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-52	0.002	5.72
	52-67	0.2	----
	67-68	0.2	5.72

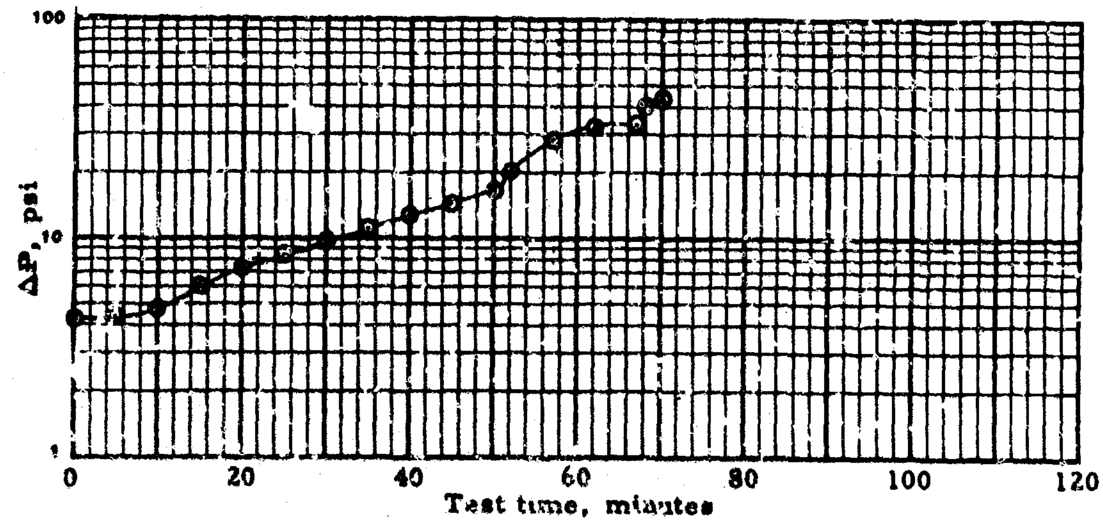


TABLE 123. SINGLE-ELEMENT LOOP TEST NO. 263
Date: 13 February 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Bowser, Part No. A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 13 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH04-006

Test duration, min	58	Calculated dirt loading, g	240
Fuel throughput, gal	1153	Actual element weight gain, g	226
Average rate, gpm	19.9		

Time	0 Min	End Test
Meter reading, gal	300	1453
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	95	65	75
IFT, distilled water, dyn/cm	44.2	33.8	36.1

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.2
pH	7.5
ST, dyn/cm	71.4

TABLE 123. SINGLE-ELEMENT LOOP TEST NO. 263 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.6	0	0			80
5	5.1	0	0	0.29	4-5	80
10	6.3	0	1		7-8	80
15	7.3	0	1		11-12	80
20	8.3	0	2			80
25	10.1	0	2		17-18	80
30	11.4	0	2			80
35	13.4	0	1		18-19	80
40	20.0	0	1*	0.27	18-19	80
45	24.5	0	2	Neg	18-19	80
50	24.5	0	1		15-16	80
55	24.9	0	1			80
58	40.0	0	1	Neg	19-20	80
59	42.2	0	1			80
60	39.2	0	1			80
62	28.4	0	1			80

* Totamitor peaked at 7 at 20 psi + 1 min.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-40	0.002	5.72
	40-55	0.2	----
	55-58	0.2	5.72

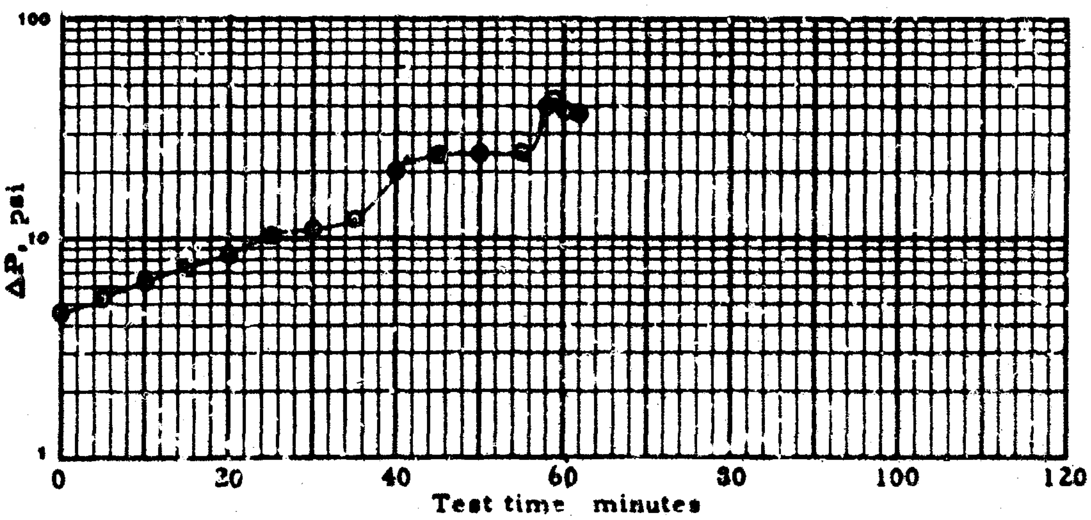


TABLE 124. SINGLE-ELEMENT LOOP TEST NO. 264
Date: 14 February 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Fram Lot 14 DoD type
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 14 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH04-006

Test duration, min	51	Calculated dirt loading, g	206
Fuel throughput, gal	1035	Actual element weight gain, g	198
Average rate, gpm	20.3		

Time	0 Min	End Test
Meter reading, gal	296	1331
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	61	79
IFT, distilled water, dyn/cm	45.8	38.2	40.5

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.08
pH	----
ST, dyn/cm	72.3

TABLE 124. SINGLE-ELEMENT LOOP TEST NO. 264 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.5	0	0			80
5	5.1	0	0	Neg	0-1	80
10	6.2	0	0			80
15	8.1	0	0			80
20	10.4	0	0			80
25	13.2	0	0			80
30	16.1	0	0			80
35	20.0	0	0	0.05	6-7	80
40	27.5	0	2			80
44	30.3	0	25	0.10	20+++	80
45	31.0	0	23		20+++	80
50	35.0	0	62		20+++	
51	40.0	0	25	0.10	20+++	
55	29.5					80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-35	0.002	5.72
35-50	0.2	----
50-51	0.2	5.72

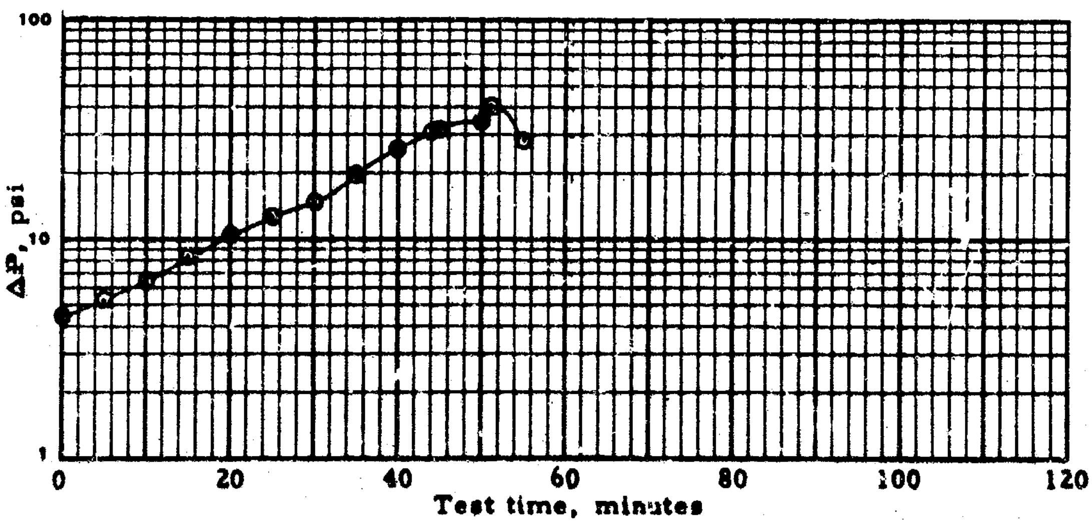


TABLE 125. SINGLE-ELEMENT LOOP TEST NO. 265
Date: 17 February 1969

Loop no.	3(Al/SS)	**Housing:**	8" I D Aluminum
		Element:	Fram Lot 14, DoD type
		Canister:	DoD Type 1

Procedure no.	13-A	**Fuel flow, gpm**	20
Water:	Filtered Tap Water	**Fuel inlet temperature, °F**	80
Solids:	Coarse AC Dust	**Fuel inlet pressure, psi**	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 17 Feb 69
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 16 **lb/Mbbl,** Santolene C **, Lot** NH04-006

Test duration, min	53	**Calculated dirt loading, g**	217
Fuel throughput, gal	1066	**Actual element weight gain, g**	197
Average rate, gpm	20.1		

Time	0 Min	End Test
Meter reading, gal	294	1360
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	95	76	74
IFT, distilled water, dyn/cm	45.8	38.2	40.3

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.2
pH	7.5
ST, dyn/cm	72.4

TABLE 125. SINGLE-ELEMENT LOOP TEST NO. 265 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.7	0	0			80
5	5.6	0	0	0.07	0-1	80
10	6.7	0	0			80
15	8.9	0	0			80
20	11.1	0	0			80
25	13.4	0	0			80
30	15.8	0	0			80
35	20.0	0	0	0.10	4-5	80
40	25.8	0	4	0.17	20+	80
45	28.4	0	4		20+	80
50	29.0	0	5		20+++	80
53	40.0	0	4	0.06	20+++	80
54	42.0	0	4			80
55	31.5					

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-35	0.002	5.72
	35-50	0.2	----
	50-53	0.2	5.72

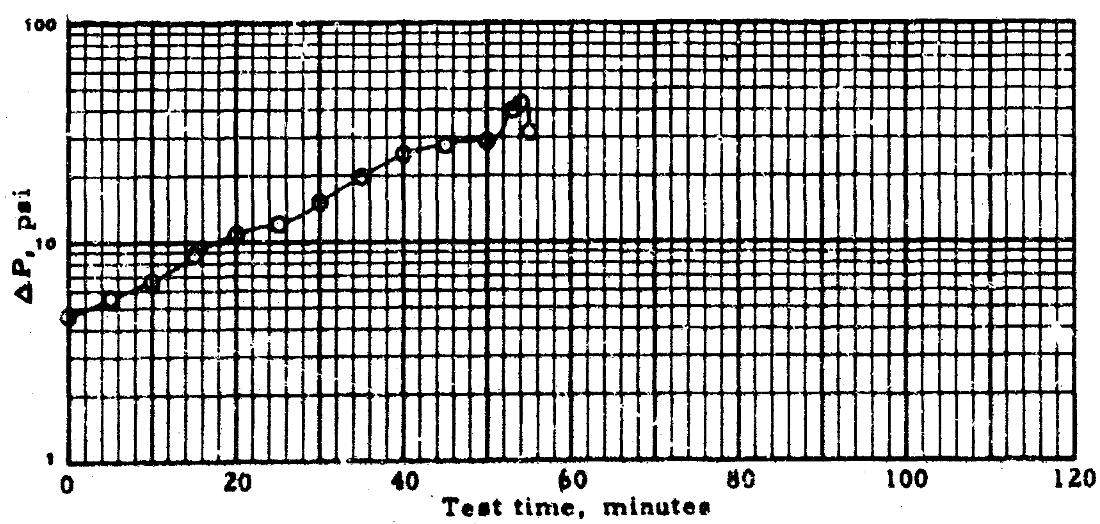


TABLE 126. SINGLE-ELEMENT LOOP TEST NO. 266
Date: 18 February 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bendix, Part No. 045800-04
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 18 Feb 69
Anti-icing additive 0.15 **vol %, Dow, Lot** 0226816
Corrosion inhibitor 16 **lb/Mbbl,** Santolene C **, Lot** NH04-006

Test duration, min 51
Fuel throughput, gal 1012
Average rate, gpm 19.8

Calculated dirt loading, g 212
Actual element weight gain, g 219

Time	0 Min	End Test
Meter reading, gal	300	1312
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	93	56	68
IFT, distilled water, dyn/cm	45.8	37.3	40.5

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	---
ST, dyn/cm	72.0

TABLE 126. SINGLE-ELEMENT LOOP TEST NO. 266 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl.	Totamitor Effl.	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.7	0	0		1-2	80
5	5.4	0	0	0.12		80
10	5.9	0	0			80
15	6.7	0	0			80
20	8.0	0	0			80
25	10.1	0	0			80
30	13.0	0	0			80
35	19.0	0	0			80
36	20.0	0	0	0.15	5-6	80
40	29.8	0	0	0.01	7-8	80
46	31.9	0	0		9-10	80
50	37.0	0	0		20	80
51	40.0	0	0	0.34	20++	80
52[a]	43.0					
52	25[b]		100+			

a. Actual time was 51 min 30 sec.
b. Probable rupture.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-36	0.002	5.[illegible]2
	36-50	0.2	----
	50-51	0.2	5.72

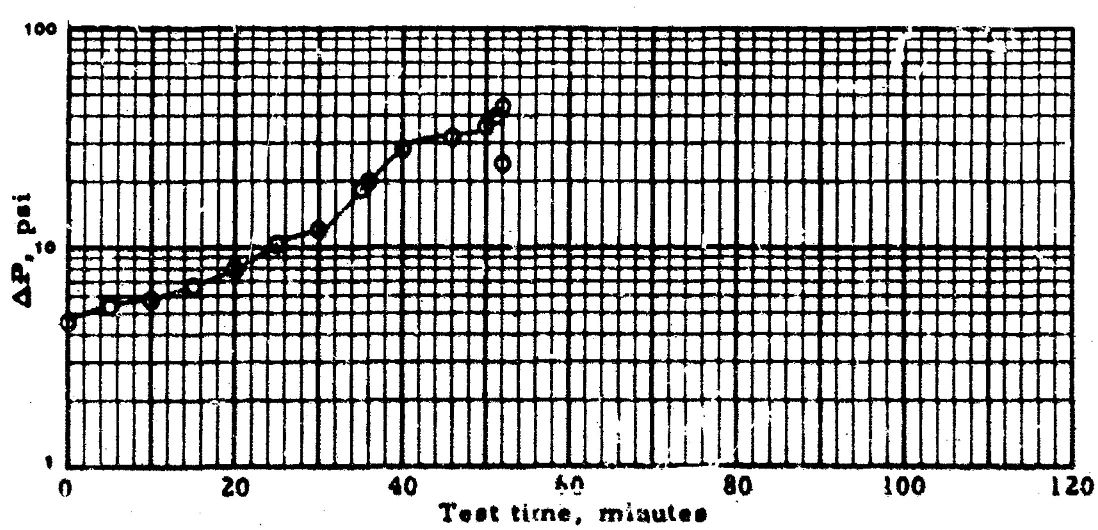


TABLE 127. SINGLE-ELEMENT LOOP TEST NO. 267
Date: 19 February 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bendix, Part No. 045800-04
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue, then, 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 19 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santclene C , Lot NH04-006

Test duration, min 62
Fuel throughput, gal 1240
Average rate, gpm 20.0

Calculated dirt loading, g 269
Actual element weight gain, g 189

Time	0 Min	End Test
Meter reading, gal	300	1540
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	90	60	58
IFT, distilled water, dyn/cm	44.1	36.6	39.4

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.4
pH	7.6
ST, dyn/cm	72.2

TABLE 127. SINGLE-ELEMENT LOOP TEST NO. 267 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.4	0	0			80
5	5.0	0	0	0.11	2-3	80
10	5.5	0	0			80
15	6.9	0	0			80
20	8.4	0	0			80
25	10.3	0	0			80
30	12.0	0	0			80
35	14.2	0	0			80
40	16.8	0	0			80
45	20.0	0	0[a]	0.07	10-11	80
50	27.9	0	0	0.05	20+	80
55	29.2	0	0		9-10	80
60	31.4	0	0		20[b]	80
62	40.0	0	0	0.07	20	80
64	40.9	0	0			80
65	32.1	0	0			80

a. Peak of 1 reached at 20 psi + 2 min.
b. 700 ml AEL sample pulled.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-45	0.002	5.72
45-60	0.2	----
60-62	0.2	5.72

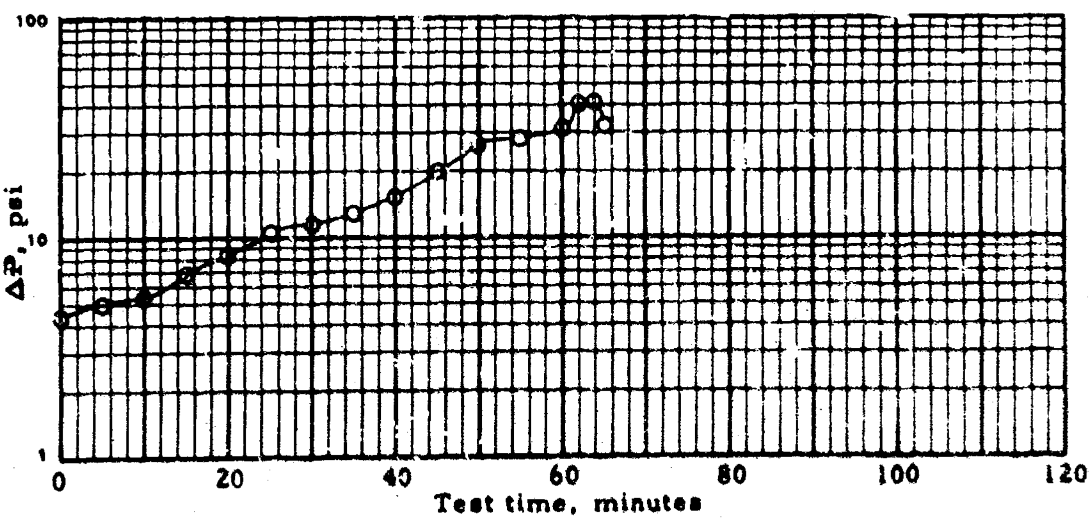


TABLE 128. SINGLE-ELEMENT LOOP TEST NO. 268
Date: 24 February 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Fram Lot 14, DoD type
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 24 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH04-006

Test duration, min 44
Fuel throughput, gal 881
Average rate, gpm 20.0

Calculated dirt loading, g 166
Actual element weight gain, g 176

Time	0 Min	End Test
Meter reading, gal	300	1181
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	87	54	76
IFT, distilled water, dyn/cm	45.4	38.0	39.0

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.3
pH	7.4
ST, dyn/cm	71.6

TABLE 128. SINGLE-ELEMENT LOOP TEST NO. 268 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.7	0	0			80
5	5.3	0	0	0.08	0-1	80
10	6.5	0	0			80
15	9.1	0	0			80
20	11.6	0	0			80
25	16.5	0	0			80
29	20.0	0	0	Neg	10-11	80
34	32.0	0	4**	Neg	20++	80
39	35.0	0	4		20++	80
44*	38.5	0	6		20+++	80
44*	40.0	0	6	0.08	20+++	80
46	46.2	0	6			80
48	39.2					80

* The ΔP of 38.5 occurred at 43 min 45 sec. 40 psi occurred at 44 min 05 sec.

**Eff totamitor peaked at 20 psi + 33 min 15 sec with a reading of 10.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-29	0.002	5.72
	29-44	0.2	----

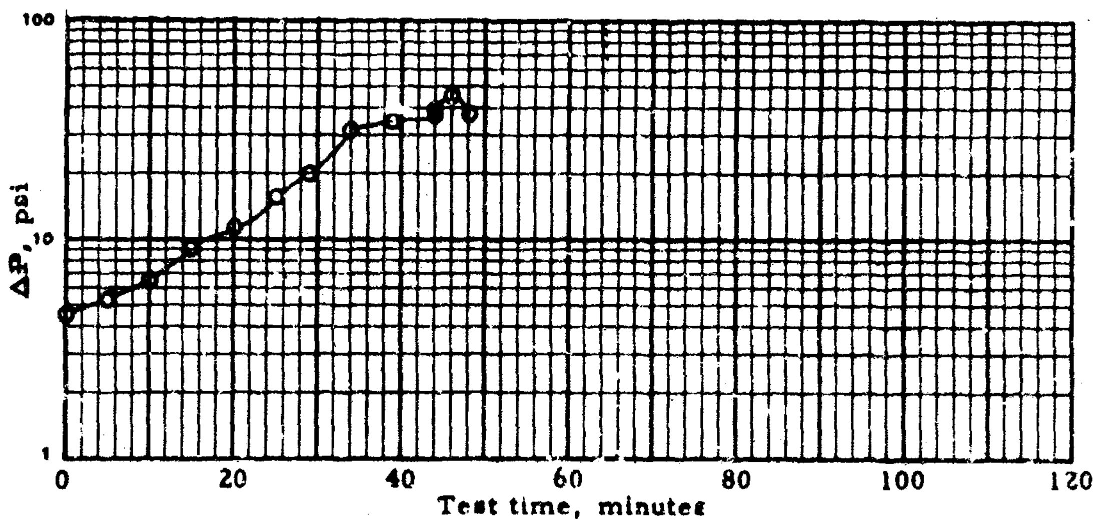


TABLE 129. SINGLE-ELEMENT LOOP TEST NO. 269
Date: 25 February 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Bendix, Part #045800-04
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 25 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH04-006

Test duration, min	66	Calculated dirt loading, g	292
Fuel throughput, gal	1315	Actual element weight gain, g	278
Average rate, gpm	19.9		

Time	0 Min	End Test
Meter reading, gal	300	1615
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	93	64	62
IFT, distilled water, dyn/cm	44.9	37.4	39.5

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.0
pH	7.3
ST, dyn/cm	71.4

TABLE 129. SINGLE-ELEMENT LOOP TEST NO. 269 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.4	0	0			80
5	4.7	0	0	0.05	0-1	80
10	5.0	0	0			80
15	6.1	0	0			80
20	7.4	0	0			80
25	9.1	0	0			80
30	11.2	0	0			80
35	12.7	0	0			80
40	14.8	0	0			80
45	17.5	0	0			80
49	20.0	0	0*	0.06	9	80
54	27.5	0	0	0.09	9	80
59	30.5	0	0		11-12	80
64	32.8	0	0		14-15	80
66	40.0	0	0	0.12	14-15	80
68	41.5	0	0			80
70	39.1	0	0			80

*Totamitor peaked at 20 psi + 1 min 30 sec with a reading of 1.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-49	0.002	5.72
	49-64	0.2	----
	64-66	0.2	5.72

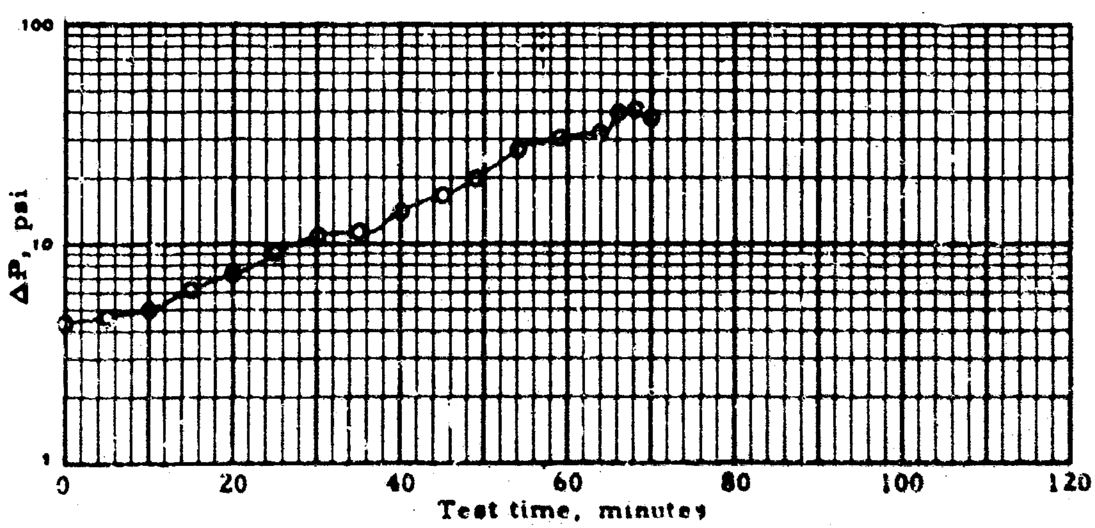


TABLE 130. SINGLE-ELEMENT LOOP TEST NO. 270
Date: 26 February 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part No. A-1389-B
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 26 Feb 69
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 16 **lb/Mbbl,** Santolene C , **Lot** NH04-16

Test duration, min	54	Calculated dirt loading, g	223
Fuel throughput, gal	1080	Actual element weight gain, g	202*
Average rate, gpm	20.0		

Time	0 Min	End Test
Meter reading, gal	300	1380
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	50	67
IFT, distilled water, dyn/cm	44.3	36.4	38.2

Analyses on injection water:

	Post Test
Time	0.4
Solids, mg/liter	7.3
pH	71.4
ST, dyn/cm	

* Small amount of dirt lost during drying.

TABLE 130. SINGLE-ELEMENT LOOP TEST NO. 270 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.6	0	0			80
5	4.9	0	0	0.01	4-5	80
10	6.5	0	0			80
15	7.5	0	0		3-4	80
20	9.5	0	0			80
25	11.5	0	0			80
30	13.0	0	0			80
35	16.5	0	0		19-20	80
37	20.0	0	0*	Neg	18-19	80
42	26.6	0	1	0.03	20	80
47	27.9	0	1		20	80
52	28.5	0	1		20	80
54	40.0	0	1	0.02	20+	80
56	41.7	0	1			80
57	34.5	0	1			80

*The effluent totamitor peaked at 20 psi + 2 min at a reading of 7.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-37	0.002	5.72
	37-52	0.2	----
	52-54	0.2	5.72

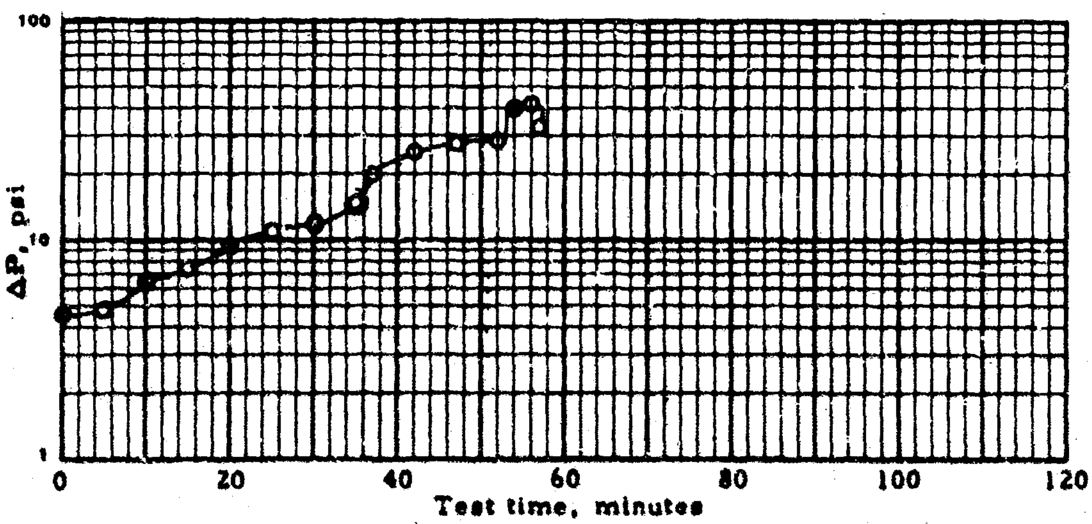


TABLE 131. SINGLE-ELEMENT LOOP TEST NO. 271
Date: 27 February 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Bowser, Part#A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 27 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH04-006

Test duration, min	45	Calculated dirt loading, g	172
Fuel throughput, gal	897	Actual element weight gain, g	163
Average rate, gpm	19.9		

Time	0 Min	End Test
Meter reading, gal	300	1197
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	76	76
IFT, distilled water, dyn/cm	43.9	37.0	38.7

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	7.4
ST, dyn/cm	71.3

TABLE 131. SINGLE-ELEMENT LOOP TEST NO. 271 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.8	0	0			80
5	5.3	0	0	0.04	0-1	80
10	7.3	0	0			80
15	8.4	0	1		10-11	80
20	12.5	0	3	0.21	14-15	80
25	14.7	0	2			80
28	20.0	0	2	0.10	10-11	80
33	27.5	0	3	0.07	20	80
38	28.1	0	11		20+++	80
43	28.2	0	22		20+++	80
45	40.0	0	16	0.19	20+++	80
46	43.5					80
48	30.6					80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-28	0.002	5.72
	28-43	0.2	----
	43-45	0.2	5.72

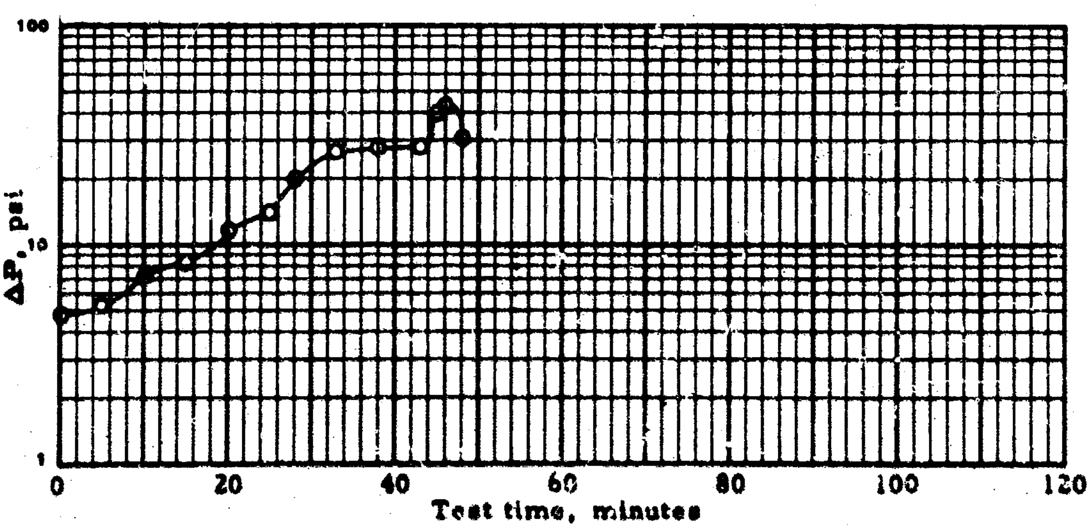


TABLE 132 . SINGLE-ELEMENT LOOP TEST NO. 272 Date: 28 Feb 69

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part #A-1389-B
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 28 Feb 69
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH04-006

Test duration, min 51
Fuel throughput, gal 1024
Average rate, gpm 20.1

Calculated dirt loading, g 206
Actual element weight gain, g 192

Time	0 Min	End Test
Meter reading, gal	300	1324
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	93	53	62
IFT, distilled water, dyn/cm	42.6	37.4	38.6

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.0
pH	7.3
ST, dyn/cm	71.8

TABLE 132. SINGLE-ELEMENT LOOP TEST NO. 272 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.9	0	0			80
5	5.8	0	0	0.06	0	80
10	7.6	0	0			80
15	8.5	0	1			80
20	11.4	0	2	0.27	12-13	80
25	12.6	0	2			80
30	15.0	0	2			80
34	20.0	0	2*	0.14	15-16	80
39	24.3	0	4	0.08	17-18	80
44	25.6	0	3		17-18	80
49	27.0	0	3		16-17	80
51	40.0	0	3	0.04	17-18	80
54	41.5	0	2			80
55	33.5					80

* At 20 psi + 1 min 30 sec the effluent totamitor peaked at a reading of 14.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-34	0.002	5.72
	34-49	0.2	----
	49-51	0.2	5.72

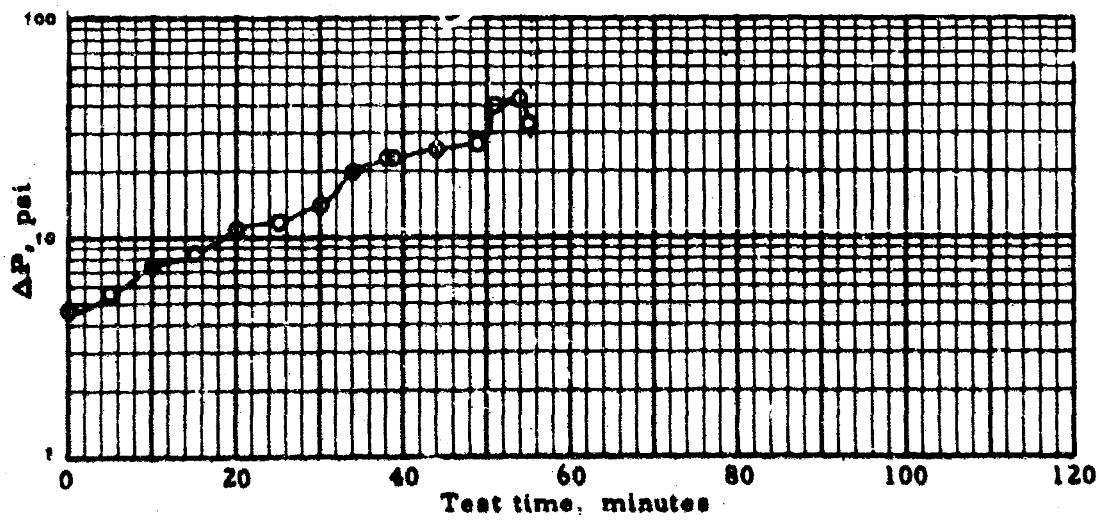


TABLE 133. SINGLE-ELEMENT LOOP TEST NO. 273 Date: 5 March 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Fram Lot 14, DoD Type
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, fresh, clay treated
Date blended with additives: 5 March 1969
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, AFA-1, Lot 37

Test duration, min 50
Fuel throughput, gal 1000
Average rate, gpm 20.0

Calculated dirt loading, g 200
Actual element weight gain, g 171

Time	0 min	End Test
Meter reading, gal	300	1300
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	98	69	77
IFT, distilled water, dyn/cm	46.9	22.5	22.8

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.2
pH	7.5
ST, dyn/cm	72.3

TABLE 133. SINGLE-ELEMENT LOOP TEST NO. 273 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.4	0	0			80
5	5.0	0	0	0.13	0-1	80
10	6.1	0	0			80
15	8.5	0	0			80
20	11.5	0	0			80
25	14.5	0	0			80
30	17.6	0	0			80
32	20.0	0	0	0.11	8-9	80
37	24.8	0	1	0.05	9-10	80
42	25.6	0	1		11-12	80
47	26.4	0	1		15-16	80
50	40.0	0	1	0.19	18-19	80
52	40.0	0	1			80
53	31.5	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-32	0.002	5.72
	32-47	0.2	----
	47-50	0.2	5.72

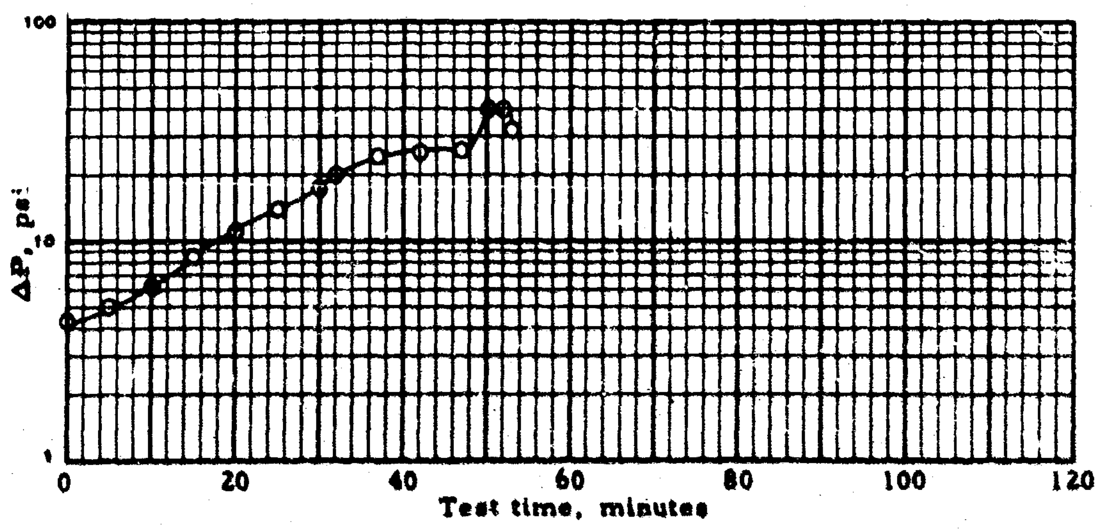


TABLE 134. SINGLE-ELEMENT LOOP TEST NO. 274
Date: 6 March 1969

Loop no. 3 (Al/SS)

Housing: 8" I D Aluminum
Element: Bendix, Part No. 045800-04
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 6 March 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 0226816
Corrosion inhibitor 16 **lb/Mbbl,** AFA-1 **, Lot** 37

Test duration, min	55
Fuel throughput, gal	1096
Average rate, gpm	19.9

Calculated dirt loading, g	229
Actual element weight gain, g	225

Time	0 Min	End Test
Meter reading, gal	300	1396
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	99	68	52
IFT, distilled water, dyn/cm	46.1	22.1	22.6

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	7.5
ST, dyn/cm	70.8

TABLE 134. SINGLE-ELEMENT LOOP TEST NO. 274 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.0	0	0			80
5	4.5	0	1	0.19	0-1	80
10	5.3	0	0			80
15	6.2	0	0			80
20	8.5	0	0			80
25	11.0	0	0			80
30	12.9	0	0			80
35	16.6	0	0			80
38	20.0	0	0*	0.03	11-12	80
43	25.2	0	1	0.06	14-15	80
48	26.4	0	1		14-15	80
53	27.3	0	1		18-19	80
55	40.0			0.11	18-19	80
57	42.3					80
58	30.5					

*Peak of 3 reached at 20 psi + 1 min 30 sec.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-38	0.002	5.72
	38-53	0.2	----
	53-55	0.2	5.72

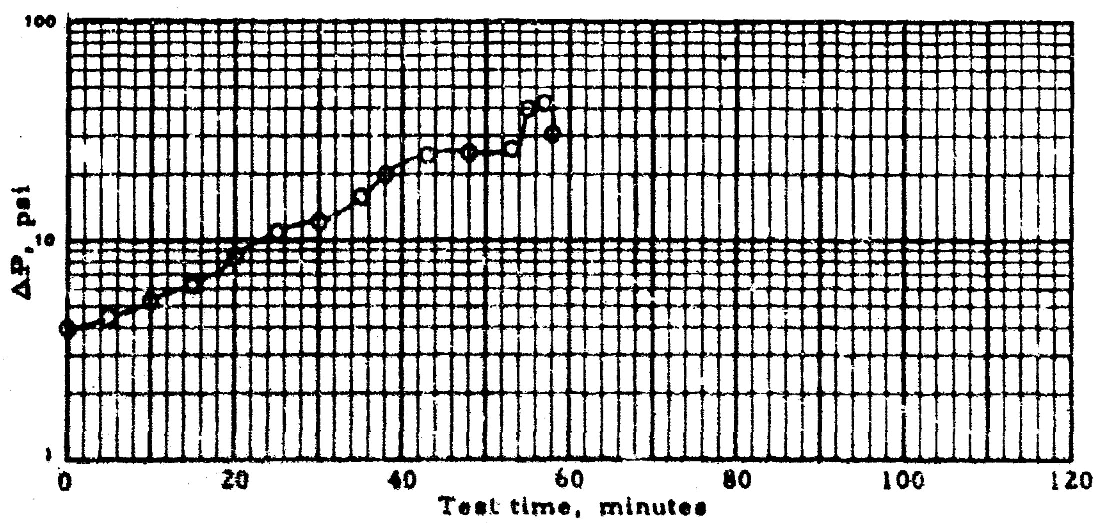


TABLE 135. SINGLE-ELEMENT LOOP TEST NO. 275
Date: 10 March 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part No. A-1389-B
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 10 March 1969
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 37

Test duration, min 57
Fuel throughput, gal 1147
Average rate, gpm 20.1

Calculated dirt loading, g 246
Actual element weight gain, g 248

Time	0 Min	End Test
Meter reading, gal	299	1446
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	92	72	77
IFT, distilled water, dyn/cm	46.2	22.5	22.4

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	7.4
ST, dyn/cm	72.1

TABLE 155. SINGLE-ELEMENT LOOP TEST NO. 275 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.6	0	0			80
5	4.9	0	0	0.09	0-1	80
10	5.5	0	0			80
15	6.8	0	0			80
20	7.9	0	0			80
25	9.5	0	0			80
30	10.8	0	0			80
35	12.4	0	0			80
40	18.5	0	0			80
41	20.0*	0	0	0.07	9-10	80
46	28.6	0	4	0.04	10-20	80
51	29.8	0	4		20+	80
56	30.9	0	4		20++	80
57	40.0	0	4	0.13	20++	80
59	42.5	0	4			80
60	35.6	0	4			80

*A peak of 7 was reached at 20 psi + 1 min.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-41	0.002	5.72
	41-56	0.2	----
	56-57	0.2	5.72

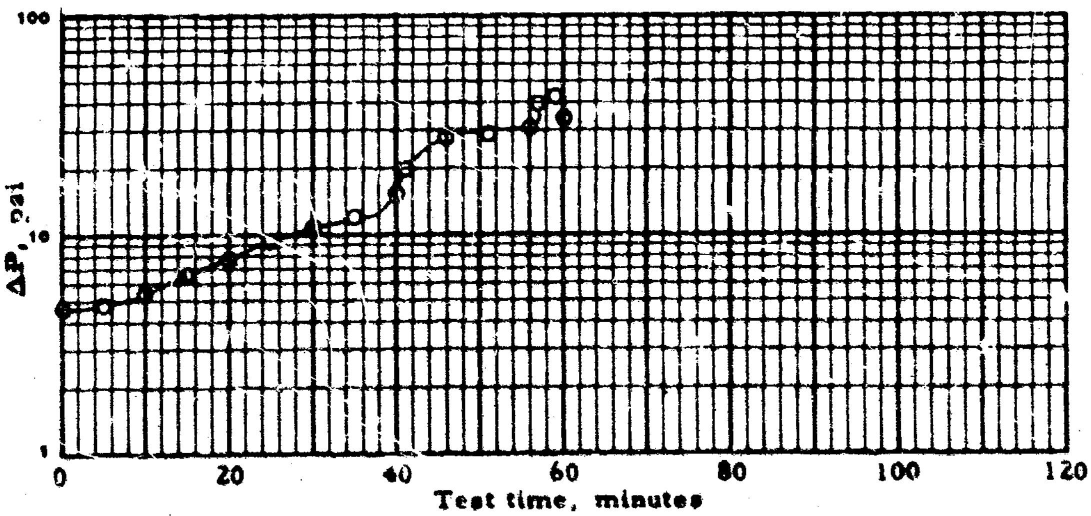


TABLE 136. SINGLE-ELEMENT LOOP TEST NO. 276
Date: 12 March 1969

Loop no.	3(Al/SS)	**Housing:**	8" I.D Aluminum
		Element:	Filter Inc, I4208 Lot 465
		Canister:	DoD Type 1

Procedure no.	13-A	**Fuel flow, gpm**	20
Water:	Filtered Tap Water	**Fuel inlet temperature, °F**	80
Solids:	Coarse AC Dust	**Fuel inlet pressure, psi**	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 11 March 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 0226816
Corrosion inhibitor 16 **lb/Mbbl,** AFA-1 **, Lot** 37

Test duration, min	67	**Calculated dirt loading, g**	297
Fuel throughput, gal	1340	**Actual element weight gain, g**	291
Average rate, gpm	20.0		

Time	0 Min	End Test
Meter reading, gal	300	1640
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	96	70	70
IFT, distilled water, dyn/cm	45.9	22.5	22.5

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.1
pH	7.6
ST, dyn/cm	71.7

TABLE 136. SINGLE-ELEMENT LOOP TEST NO. 276 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.4	0	0			80
5	4.1	0	0	0.06	1-2	80
10	4.1	0	0			80
15	4.2	0	0			80
20	4.5	0	0			80
25	4.8	0	0			80
30	5.3	0	0			80
35	6.6	0	0			80
40	9.1	0	0			80
45	14.8	0	0			80
49	20.0	0	0	0.02	4-5	80
54	25.2	0	0	0.09	5	80
59	26.5	0	0		6-7	80
64	28.8	0	0		20	80
67	40.0	0	0	0.09	20	80
69	41.3	0	0			80
70	38.5	0	0			80

Schedule:	Minutes	Water, gpm	Solids, g/min

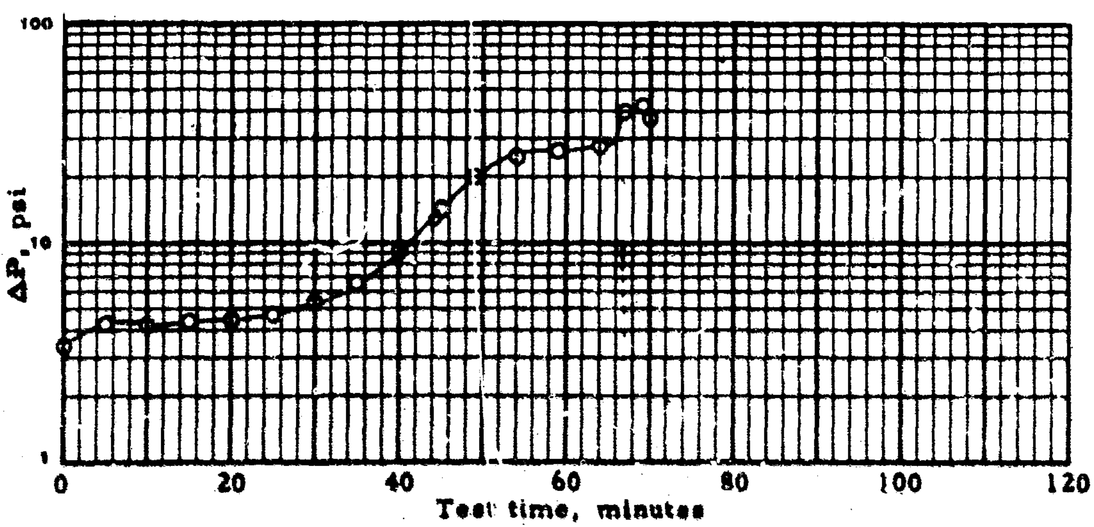


TABLE 137. SINGLE-ELEMENT LOOP TEST NO. 277
Date: 13 March 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part No. A-1389-B
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 13 March 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 16 **lb/Mbbl,** AFA-1 **, Lot** 37

Test duration, min 53
Fuel throughput, gal 1057
Average rate, gpm

Calculated dirt loading, g 217
Actual element weight gain, g 203

Time	0 Min	End Test
Meter reading, gal	299	1356
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	95	50	69
IFT, distilled water, dyn/cm	45.3	22.5	21.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	7.7
ST, dyn/cm	71.3

TABLE 137. SINGLE-ELEMENT LOOP TEST NO. 277 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.5	0	0			80
5	4.8	0	0	0.05	0-1	80
10	6.3	0	0			80
15	7.8	0	0			80
20	10.4	0	0			80
25	11.7	0	0			80
30	14.5	0	0			80
35	20.0	0	1	0.05	20	80
40	22.5	0	9	0.14	20++	80
45	23.1	0	8		20+++	80
50	23.6	0	8		20+++	80
52	40.0	0	19*	0.07	20+++	80
55	38.8	0	9			80
56	32.5	0	1			80

* Peak of 19 reached at 20 psi plus 17 min 30 sec.

Schedule:	Minutes	Water, gpm	Solids, g/min

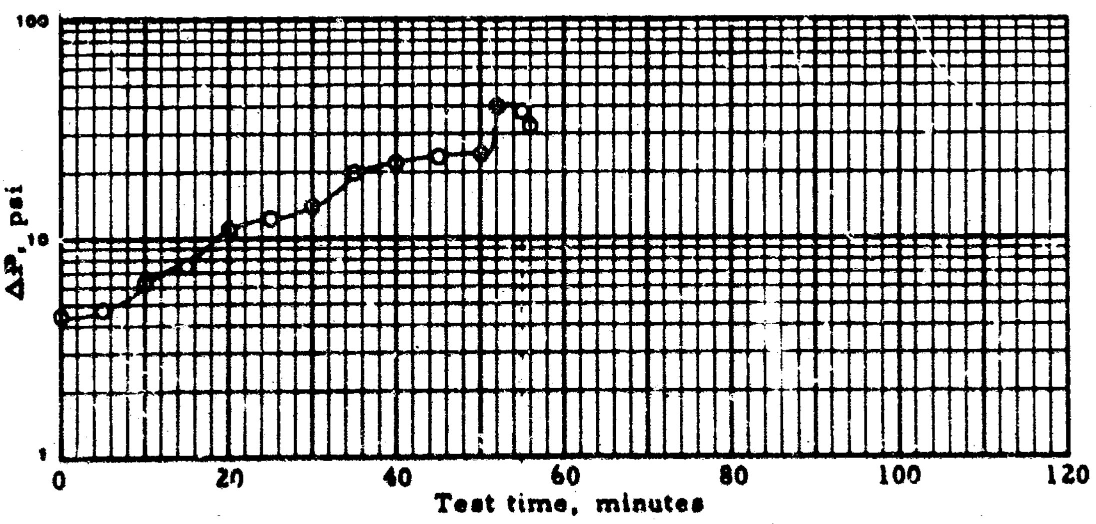


TABLE 138. SINGLE-ELEMENT LOOP TEST NO. 278
Date: 17 March 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Filter Inc, I4208 Lot 465
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 70
Fuel inlet pressure, psi 80

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 17 Feb 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 16 **lb/Mbbl,** AFA-1 **, Lot**

Test duration, min	69	Calculated dirt loading, g	315
Fuel throughput, gal	1381	Actual element weight gain, g	316
Average rate, gpm			

Time	0 Min	End Test
Meter reading, gal	300	1681
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	95	68	67
IFT, distilled water, dyn/cm	46.3	22.4	22.4

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	7.9
ST, dyn/cm	71.1

TABLE 138. SINGLE-ELEMENT LOOP TEST NO. 278 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.9	0	0			
5	3.9	0	0	0.12	1-2	
10	4.1	0	0			
15	4.4	0	0			
20	4.6	0	0			
25	5.0	0	0			
30	5.7	0	0			
35	6.6	0	0			
40	8.1	0	0			
45	10.5	0	0			
50	15.4	0	0			
53	20.0	0	0*	0.18	7-8	
58	26.5	0	1	0.05	10-11	
63	28.3	0	1			
68	30.4	0	1			
69	40.0	0	1	0.08	20	
71	41.7	0	1		17-18	
72	38.5	0	1			

*A peak of 1 began at 20 psi + 45 sec and remained throughout the test.

Schedule:	Minutes	Water, gpm	Solids, g/min

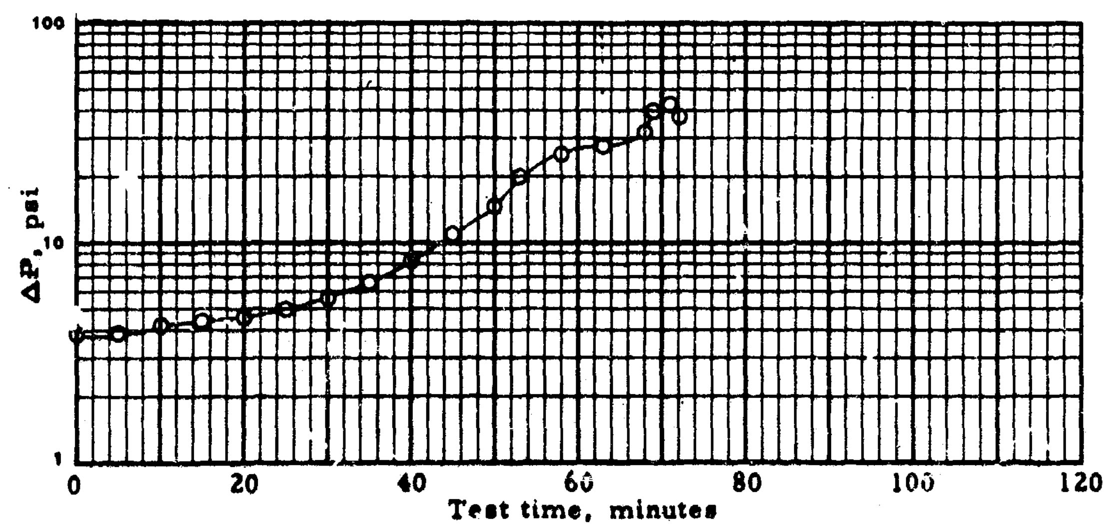


TABLE 139. SINGLE-ELEMENT LOOP TEST NO. 279
Date: 28 March 1969

Loop no. 3(Al/SS)		**Housing:**	8" I D Aluminum
		Element:	Bendix, Part No. 045800-04
		Canister:	DoD Type 1

Procedure no.	13-A	**Fuel flow, gpm**	20
Water:	Filtered Tap Water	**Fuel inlet temperature, °F**	80
Solids:	Coarse AC Dust	**Fuel inlet pressure, psi**	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 28 March 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 16 **lb/Mbbl,** AFA-1 **, Lot** 37

Test duration, min	52	**Calculated dirt loading, g**	217
Fuel throughput, gal	1045	**Actual element weight gain, g**	216
Average rate, gpm	20.1		

Time	0 Min	End Test
Meter reading, gal	300	1346
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	99	57	56
IFT, distilled water, dyn/cm	46.2	22.5	22.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.4
pH	7.5
ST, dyn/cm	72.1

TABLE 139. SINGLE-ELEMENT LOOP TEST NO. 279 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.8	0	0			80
5	4.4	0	0	0.13	1-2	80
10	5.3	0	0			80
15	7.3	0	0			80
20	9.4	0	0			80
25	11.7	0	0			80
30	14.9	0	0			80
35	18.9	0	0			80
36	20.0	0	0	0.06	9-10	80
41	28.3	0	1	0.01	11-12	80
46	29.3	0	1		11-12	80
51	29.9	9	2		17-18	80
52	40.0	0	2	0.13	17-18	80
54	42.3	0	2			80
55	33.0	0	2			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-36	0.002	5.72
36-51	0.2	----
51-52	0.2	5.72

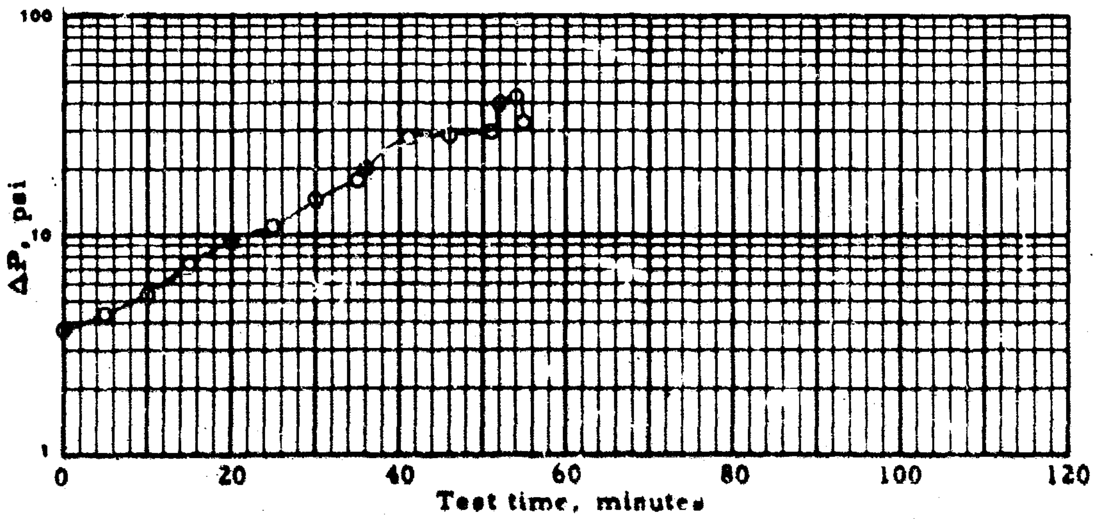


TABLE 140. SINGLE-ELEMENT LOOP TEST NO. 280
Date: 1 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Fram, Lot 14
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then
0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then
discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 ,reused, clay treated
Date blended with additives: 1 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 57

Test duration, min	46	Calculated dirt loading, g	177
Fuel throughput, gal	919	Actual element weight gain, g	170
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	300	1219
Screen ΔP, psi	2	2
Cleanup ΔP, psi	2	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	98	80	82
IFT, distilled water, dyn/cm	46.7	20.8	21.2

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.0
pH	7.5
ST, dyn/cm	70.8

TABLE 140. SINGLE-ELEMENT LOOP TEST NO. 280 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.2	0	0			80
5	4.8	0	1	0.16	0-1	80
10	5.6	0	1			80
15	8.2	0	1			80
20	11.1	0	0			80
25	15.4	0	0			80
29	20.0	0	0	0.10	9-10	80
34	29.1	0	1	0.19	9-10	80
39	29.6	0	1		11-12	80
44	30.4	0	2		20	80
46	40.0	0	2	0.06	20	80
48	41.5	0	2			80
49	31.5	0	2			80

* Peak of 4 reached at 20 psi + 1 min.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-29	0.002	5.72
	29-44	0.2	----
	44-46	0.2	5.72

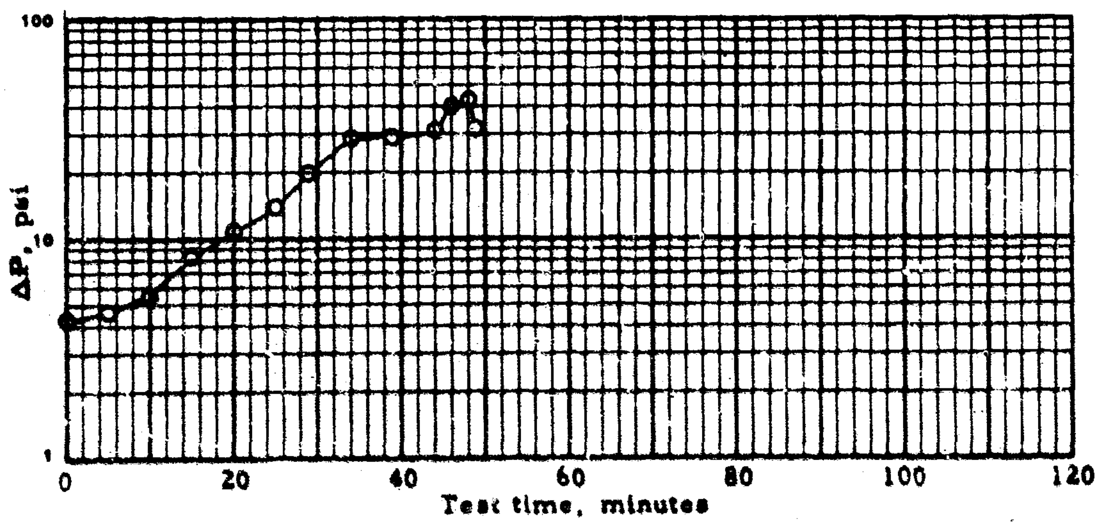


TABLE 141. SINGLE-ELEMENT LOOP TEST NO. 281
Date: 2 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Fram, Lot 14
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	70
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	80

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 2 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1, Lot 37

Test duration, min	48	Calculated dirt loading, g	194
Fuel throughput, gal	966	Actual element weight gain, g	180
Average rate, gpm	20.1		

Time	0 min	End Test
Meter reading, gal	300	1266
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	99	77	86
IFT, distilled water, dyn/cm	44.1	22.5	22.1

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	7.7
ST, dyn/cm	71.7

TABLE 141. SINGLE-ELEMENT LOOP TEST NO. 281 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.3	0	0			80
5	5.5	0	1	0.20	1-2	80
10	6.5	0	1			80
15	9.2	0	1			80
20	11.8	0	0			80
25	14.8	0	0			80
30	18.8	0	0			80
31	20.0	0	0*	0.07	7-8	80
36	24.3	0	1	0.11	17-18	80
41	24.8	0	1		15-16	80
46	26.5	0	1		10-11	80
49	40.0	0	1	0.34	18-19	80
51	40.6	0	1			80
52	30.8	0	1			80

* Peak of 2 reached at 20 psi + 1 min 30 sec.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-31	0.002	5.72
31-46	0.2	----
46-49	0.2	5.72

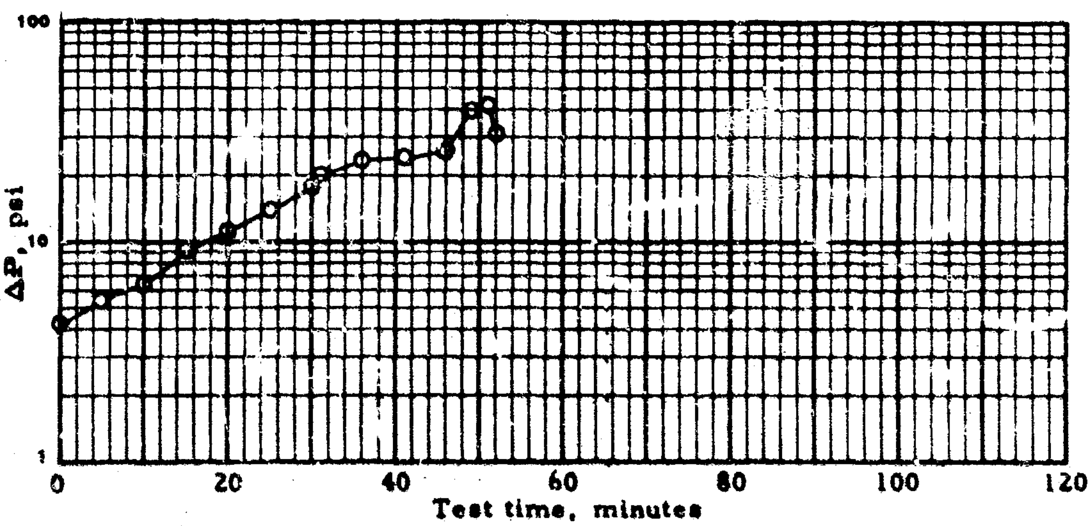


TABLE 142. SINGLE-ELEMENT LOOP TEST NO. 282
Date: 3 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Filters Inc, I4208 Lot 465
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 3 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA -1, Lot 37

Test duration, min	58	Calculated dirt loading, g	292
Fuel throughput, gal	1152	Actual element weight gain, g	297
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	300	1452
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	75	72
IFT, distilled water, dyn/cm	45.5	22.3	22.5

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	7.9
ST, dyn/cm	71.5

TABLE 142. SINGLE-ELEMENT LOOP TEST NO. 282 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.4	0	0			80
5	3.8	0	0	0.09	0-1	80
10	3.8	0	0			80
15	4.1	0	0			80
20	4.4	0	0			80
25	4.6	0	0			80
30	5.1	0	0			80
35	6.0	0	0			80
40	7.6	0	0			80
45	10.3	0	0			80
51	20.0	0	0	0.10	9-10	80
56	28.5	0	0	0.12	9-10	80
58	40.0	0	0	0.08		80
60	41.5	0	0			80
62	35.0	0	0			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-51	0.002	5.72
	51-58	0.2	----

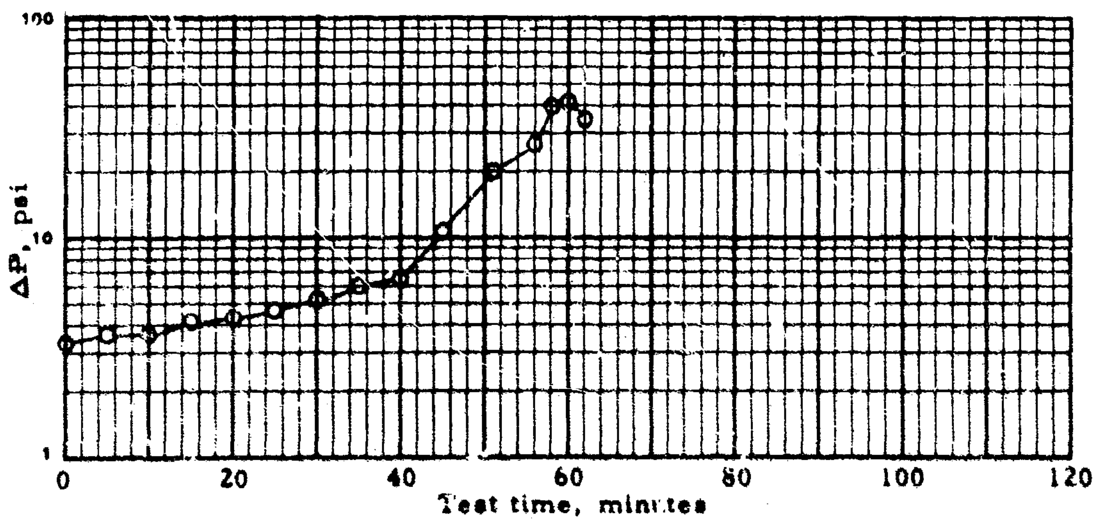


TABLE 143. SINGLE-ELEMENT LOOP TEST NO. 283
Date: 4 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Bowser, Part No. A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 4 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 37

Test duration, min	58	Calculated dirt loading, g	246
Fuel throughput, gal	1139	Actual element weight gain, g	226
Average rate, gpm	19.6		

Time	0 min	End Test
Meter reading, gal	297	1436
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	78	66
IFT, distilled water, dyn/cm	45.1	22.5	22.3

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.4
pH	7.5
ST, dyn/cm	71.6

TABLE 143. SINGLE-ELEMENT LOOP TEST NO. 283 (Cont'd)

Time, min	ΔP, psi	Totamitor		Effluent, mg/liter		Influent fuel temperature, °F
		Infl	Effl	Solids	Free water	
0	4.0	0	0			80
5	5.0	0	0	0.12	1-2	80
10	6.5	0	0			80
15	8.0	0	0			80
20	9.5	0	0			80
25	11.5	0	0			80
30	12.3	0	0			80
35	14.0	0	0			80
40	18.8	0	2			80
41	20.0	0	25*	0.11	20+	80
46	28.0	0	25	0.07	20+++	80
51	29.6	0	19		20+++	80
56	30.7	0	14		20+++	80
58	40.0	0	32	0.18	20+++	80
59	44.0	0	100**			80

* Peak of 38 reached at 20 psi + 2 min.
** Probable rupture of element.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-41	0.002	5.72
	41-56	0.2	----
	56-58	0.2	5.72

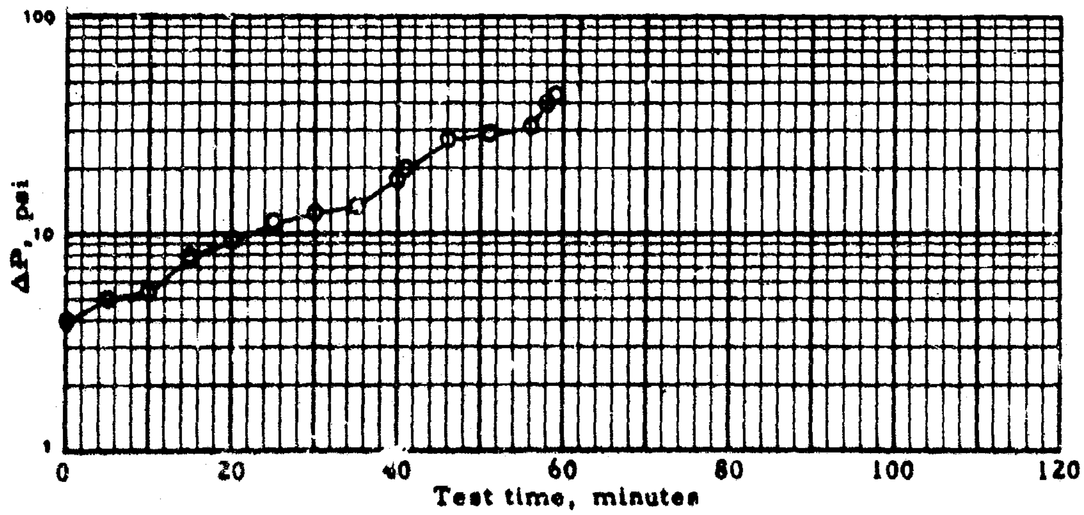


TABLE 144. SINGLE-ELEMENT LOOP TEST NO. 284
Date: 7 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Bendix, Part No. 045800-04
		Canister:	DoD Type 1
Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused clay treated
Date blended with additives: 7 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1, Lot 37

Test duration, min	52	Calculated dirt loading, g	212
Fuel throughput, gal	1043	Actual element weight gain, g	203
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	1343
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	96	63	56
IFT, distilled water, dyn/cm	44.6	22.8	22.9

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.2
pH	7.5
ST, dyn/cm	71.1

TABLE 144. SINGLE-ELEMENT LOOP TEST NO. 284 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.0	0	0			80
5	4.6	0	1	0.23	2-3	80
10	5.5	0	0			80
15	7.5	0	0			80
20	9.6	0	0			80
25	12.3	0	0			80
30	15.4	0	0			80
34	20.0	0	0	0.06	8-9	80
39	24.3	0	0	0.05	10-11	80
44	24.6	0	1		8-9	80
49	25.0	0	1		9-10	80
52	40.0	0	1	0.06	20+	80
54	41.4	0	1			80
55	31.5	0	1			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-34	0.002	5.72
34-49	0.2	----
49-52	0.2	5.72

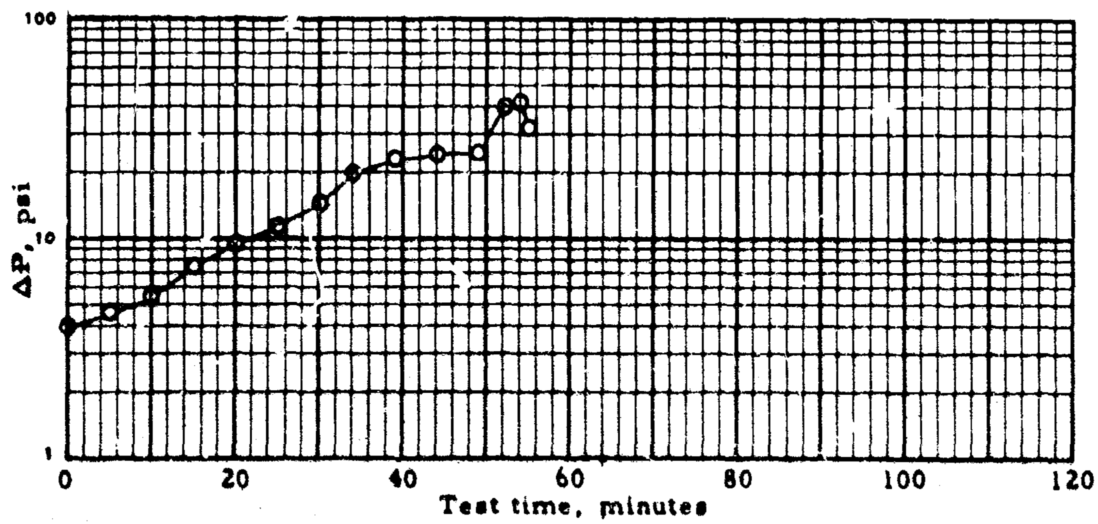


TABLE 145. SINGLE-ELEMENT LOOP TEST NO. 285
Date: 8 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Bendix, Part No. 045800-04
		Canister:	DoD Type 1

Proceaure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 8 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 37

Test duration, min	50	Calculated dirt loading, g	206
Fuel throughput, gal	1009	Actual element weight gain, g	192
Average rate, gpm	20.2		

Time	0 min	End Test
Meter reading, gal	300	1309
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	99	70	53
IFT, distilled water, dyn/cm	44.2	22.9	22.7

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	8.1
ST, dyn/cm	69.6

TABLE 145. SINGLE-ELEMENT LOOP TEST NO. 285 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.9	0	0			80
5	4.4	0	2	0.18	0-1	80
10	5.1	0	1			80
15	7.5	0	0			80
20	10.3	0	0			80
25	14.2	0	0			80
30	18.0	0	0			80
33	20.0	0	0	0.07	18-19	80
38	25.9	0	0	0.08	17-18	80
43	27.2	0	0		17-18	80
48	28.2	0	0		20	80
50	40.0	0	0	0.03	18-19	80
52	42.1	0	0			80
54	29.8	0	0			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-33	0.002	5.72
33-48	0.2	----
48-50	0.2	5.72

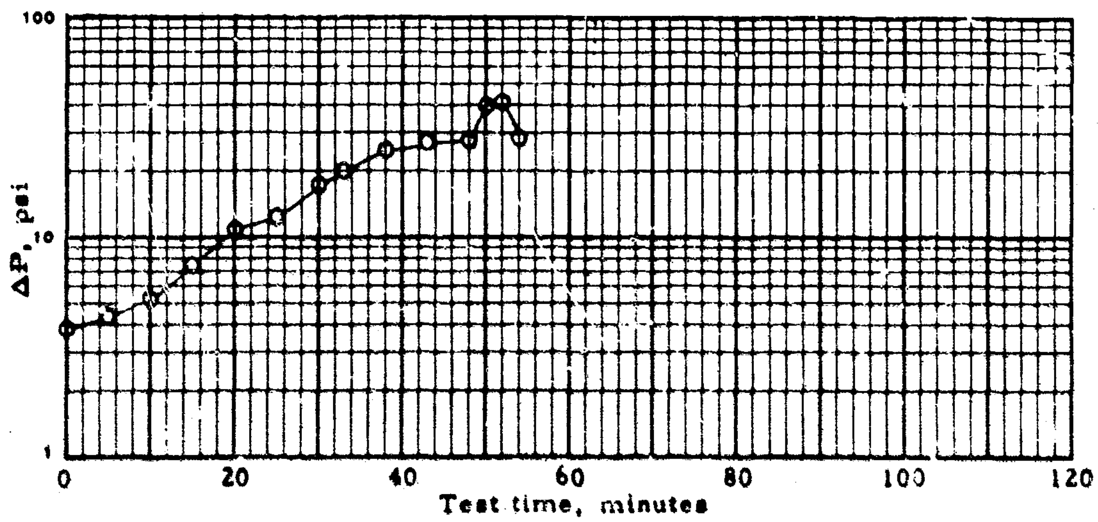


TABLE 146. SINGLE-ELEMENT LOOP TEST NO. 286
Date: 14 April 1969

Loop no.	3(A1/S3)	Housing:	8" ID Aluminum
		Element:	Bowser, A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then, 0.2 gpm from 20 psi to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then, 0 g/min from 20 psi to 20 psi + 15 min., then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 14 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 37

Test duration, min	55	Calculated dirt loading, g	229
Fuel throughput, gal	1101	Actual element weight gain, g	212
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	295	1396
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	65	72
IFT, distilled water, dyn/cm	44.3	22.5	22.4

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	7.9
ST, dyn/cm	70.7

TABLE 146. SINGLE-ELEMENT LOOP TEST NO. 286 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.0	0	0			80
5	5.5	0	0	0.26	*	80
10	5.5	0	0		9-10	80
15	8.5	0	0		8-9	80
20	9.5	0	0		7-8	80
25	10.5	0	0		7-8	80
30	12.5	0	0		9-9	80
35	15.8	0	0		7-8	80
38	20.0	0	1	0.28	18-19	80
43	27.7	0	1	0.17	20+	80
48	28.5	0	2		15-16	80
53	30.2	0	2		20+	80
55	40.0	0	3	0.09	20+++	80
57	42.0					80

* AEL pads not readable.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-38	0.002	5.72
38-53	0.2	----
53-55	0.2	5.72

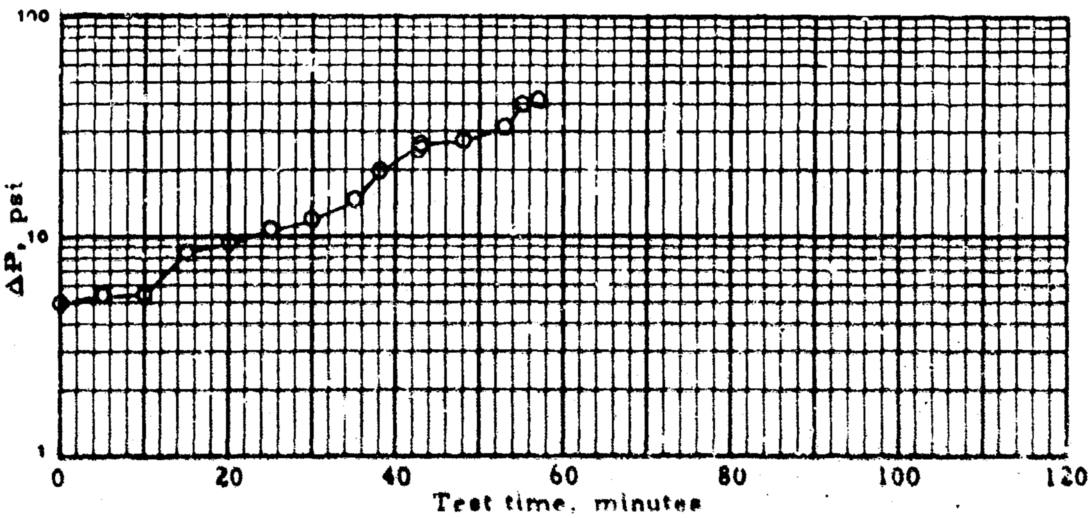


TABLE 147. SINGLE-ELEMENT LOOP TEST NO. 287
Date: 15 April 1969

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Filters Inc, I4208 Lot 465
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtred Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 15 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 37

Test duration, min 51
Fuel throughput, gal 1016
Average rate, gpm 19.9

Calculated dirt loading, g 200
Actual element weight gain, g 202

Time	0 min	End Test
Meter reading, gal	298	1314
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	99	81	79
IFT, distilled water, dyn/cm	43.4	22.5	22.4

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.2
pH	7.9
ST, dyn/cm	71.6

TABLE 147. SINGLE-ELEMENT LOOP TEST NO. 287 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.7	0	0			80
5	3.7	0	0	0.20	4-5	80
10	4.0	0	0		2-3	80
15	4.2	0	0			80
20	5.1	0	0			80
25	6.9	0	0			80
30	11.1	0	0			80
34	20.0	0	0	0.25	16-17	80
39	27.9	0	0	Neg	20	80
44	30.0	0	0		19-20	80
49	32.3	0	0		20+	80
51	40.0	0	0	Neg	20	80
53	41.5	0	0			80
54	38.3	0	0			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-34	0.002	5.72
	34-49	0.2	----
	49-51	0.2	5.72

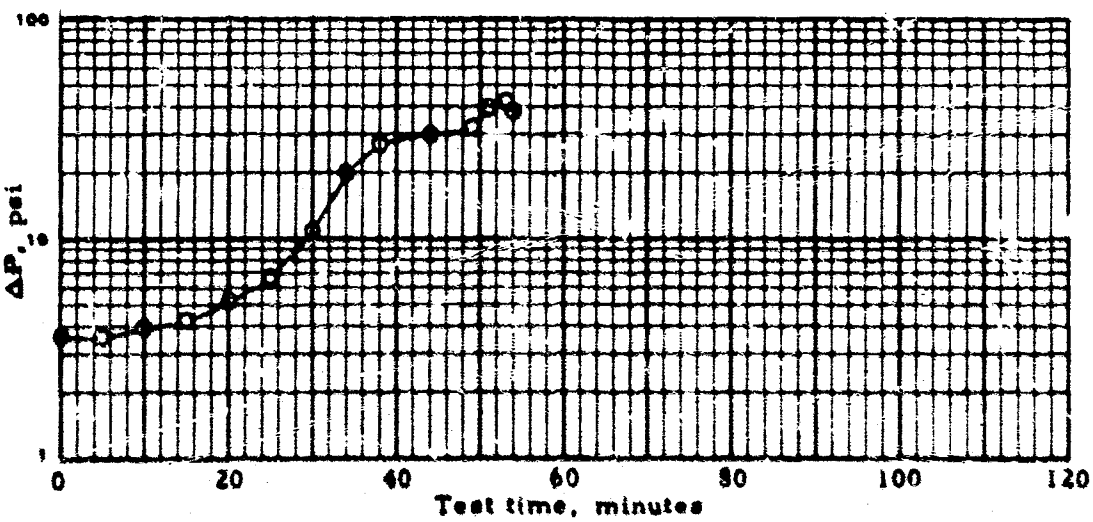


TABLE 148. SINGLE-ELEMENT LOOP TEST NO. 288
Date: 16 April 1969

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Fram, Lot 14
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 16 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 16 lb/Mbbl, AFA-1 , Lot 37

Test duration, min	45
Fuel throughput, gal	900
Average rate, gpm	20.0
Calculated dirt loading, g	172
Actual element weight gain, g	157

Time	0 min	End Test
Meter reading, gal	300	1200
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	95	86	84
IFT, distilled water, dyn/cm	43.1	23.3	22.9

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.0
pH	7.4
ST, dyn/cm	73.4

TABLE 148. SINGLE-ELEMENT LOOP TEST NO. 288 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	0	0			80
5	4.7	0	1	0.02	1-2	80
10	6.1	0	1		3-4	80
15	8.8	0	0			80
20	12.8	0	0			80
25	16.4	0	0			80
28	20.0	0	0	Neg	16-17	80
33	26.1	0	1	0.33	18-19	80
38	25.4	0	1		17-18	80
43	26.5	0	1		20	80
45	40.0	0	1	0.26	20	80
47	41.3	0	1			80
48	32.5	0	0			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-28	0.002	5.72
28-43	0.2	----
43-45	0.2	5.72

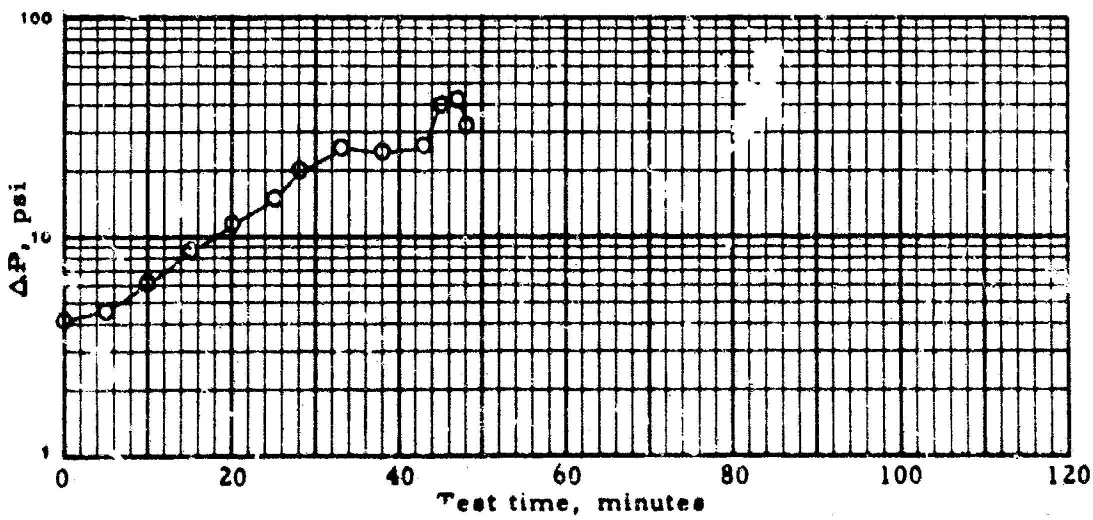


TABLE 149. SINGLE-ELEMENT LOOP TEST NO. 289
Date: 22 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Fram, Lot 14
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , fresh, clay treated
Date blended with additives: 22 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	27	Calculated dirt loading, g	137
Fuel throughput, gal	540	Actual element weight gain, g	122
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	840
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	98	53	64
IFT, distilled water dyn/cm	46.7	24.8	24.8

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.1
pH	7.8
ST, dyn/cm	71.4

TABLE 149. SINGLE-ELEMENT LOOP TEST NO. 289 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.3	0	0			80
5	4.6	0	1	0.47	3-4	80
10	5.5	0	1			80
15	8.6	0	1			80
20	13.8	0	1			80
24	20.0	0	1	0.73	20	80
27	40.0	0	83	1.78		80
29	43.5	0	100+			80
30	36.3	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-24	0.002	5.72
	24-27	0.2	----

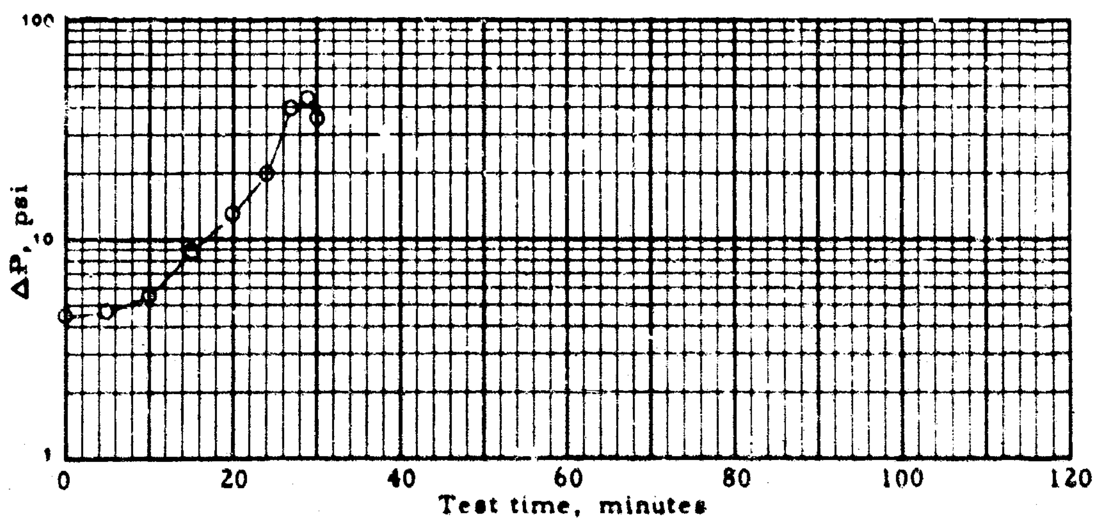


TABLE 150. SINGLE-ELEMENT LOOP TEST NO. 290
Date: 23 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Filters Inc, I4208 Lot 465
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids.	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 23 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	38	Calculated dirt loading, g	212
Fuel throughput, gal	760	Actual element weight gain, g	213
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	1060
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	98	53	64
IFT, distilled water, dyn/cm	46.3	24.8	24.5

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.0
pH	--
ST, dyn/cm	71.2

TABLE 150. SINGLE-ELEMENT LOOP TEST NO. 290 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.3	0	0			80
5	3.8	0	0	0.28	3-4	80
10	3.6	0	0			80
15	4.1	0	0			80
20	4.4	0	0			80
25	5.0	0	0			80
30	6.4	0	0			80
35	11.2	0	0			80
37	20.0	0	0	1.02	20+	80
38	40.0	0	9		20+++	80
39	50+	0	100+			80
40	---	0	100+			80
42	---	0	5			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-37	0.002	5.72
	37-38	0.2	----

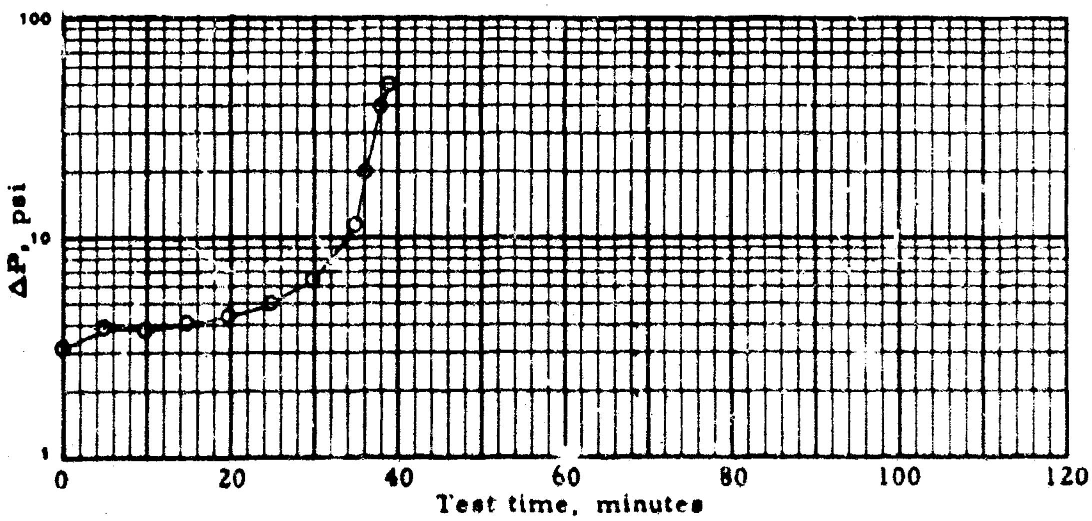


TABLE 151. SINGLE-ELEMENT LOOP TEST NO. 291
Date: 24 April 1969

Loop no.	3(Al/SS)	**Housing:**	8" ID Aluminum
		Element:	Bowser, Part No. A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	**Fuel flow, gpm**	20
Water:	Filtered Tap Water	**Fuel inlet temperature, °F**	80
Solids:	Coarse AC Dust	**Fuel inlet pressure, psi**	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 24 April 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 20 **lb/Mbbl,** Lubrizol 541 **, Lot** 24794

Test duration, min	35	**Calculated dirt loading, g**	172
Fuel throughput, gal	699	**Actual element weight gain, g**	107
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	299	1000
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	98	65	80
IFT, distilled water, dyn/cm	46.2	24.3	25.9

Analyses on injection water:

Time	Post Test
Solids, mg/liter	0.3
pH	7.8
ST, dyn/cm	71.2

TABLE 151. SINGLE-ELEMENT LOOP TEST NO. 291 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.3	0	0			80
5	5.0	0	0	0.18	18-19	80
10	5.9	0	2		20	80
15	7.5	0	1		20	80
20	9.5	0	1			80
25	13.6	0	2			80
30	20.0	0	2	0.16	20+	80
34	37.5	0	100+	Neg	20+++	80
35	40.0	0	100+		20+++	80
36	43.5	0	100+			80
38	33.4	0	30			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-30	0.002	5.72
	30-35	0.2	----

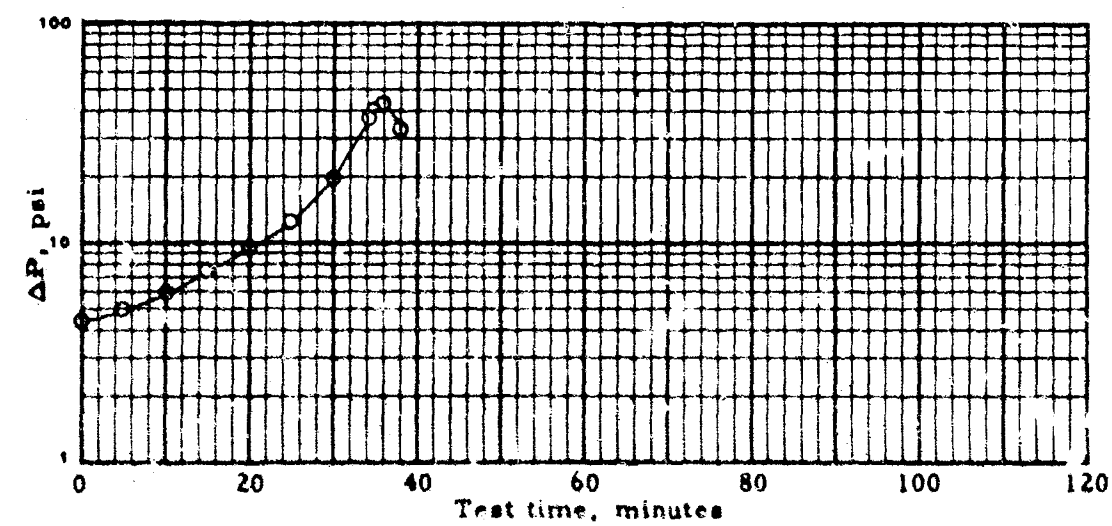


TABLE 152. SINGLE-ELEMENT LOOP TEST NO. 292
Date: 25 April 1969

Loop no. 3(Al/SS)

Housing: 8" ID Aluminum
Element: Bendix, Part No. 045800-04
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 25 April 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 20 **lb/Mbbl,** Lubrizol 541 **, Lot** 24794

Test duration, min	27
Fuel throughput, gal	564
Average rate, gpm	20.9
Calculated dirt loading, g	114
Actual element weight gain, g	128

Time	0 min	End Test
Meter reading, gal	322	886
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	96	75	62
IFT, distilled water, dyn/cm	45.7	25.7	26.7

Analyses on injection water:

Time	Post Test
Solids, mg/liter	----
pH	7.9
ST, dyn/cm	61.4

TABLE 152. SINGLE-ELEMENT LOOP TEST NO. 292 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.8	0	0			80
5	4.5	0	2	0.60	12	80
10	5.6	0	1			80
15	10.0	0	1			80
20	20.0	0	1	0.54	20+++	80
25	37.7	0	63	0.98	20+++	80
27	40.0	0	100+	1.12	20+++	80
31	41.2	0	100+			80
33	35.0	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-20	0.002	5.72
	20-27	0.2	----

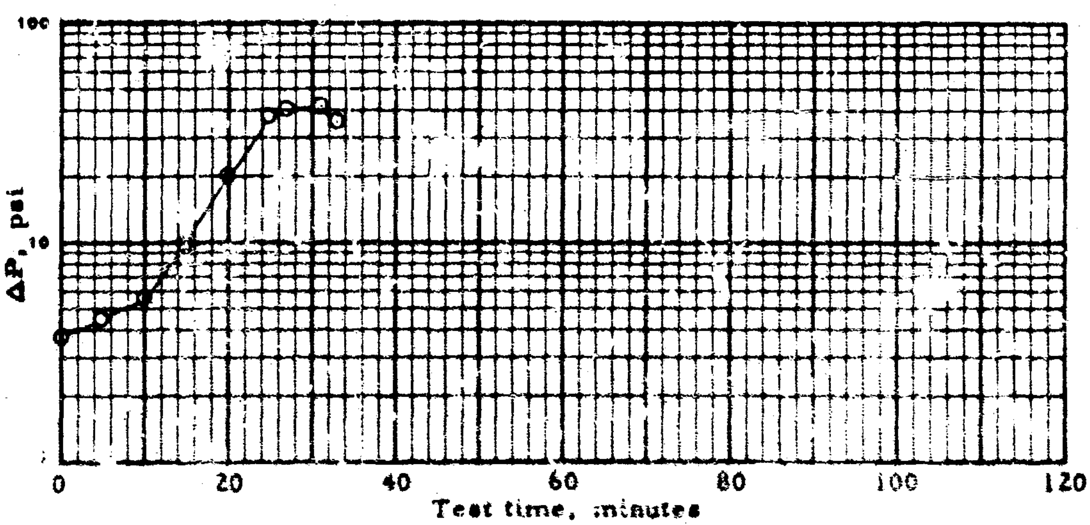


TABLE 153. SINGLE-ELEMENT LOOP TEST NO. 293
Date: 29 April 1969

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Bowser, Part No. A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 28 April 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	33	Calculated dirt loading, g	177
Fuel throughput, gal	665	Actual element weight gain, g	178
Average rate, gpm	20.1		

Time	0 min	End Test
Meter reading, gal	300	965
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	97	74	59
IFT, distilled water, dyn/cm	45.3	25.6	26.6

Analyses on injection water:

Time	Post Test
Solids, mg/liter	Neg
pH	7.7
ST, dyn/cm	71.6

TABLE 153. SINGLE-ELEMENT LOOP TEST NO. 293 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.9	0	0			80
5	6.5	0	0	0.41	15-16	80
10	8.1	0	4		20++	80
15	10.2	0	5		20+	80
20	11.5	0	1			80
25	13.5	0	1			80
30	18.8	0	3			80
31	20.0	0	3	0.30	20++	80
33	40.0	0	100+	3.96	20+++	80
34	50+	0	100+			80
37	----	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-31	0.002	5.72
	31-33	0.2	----

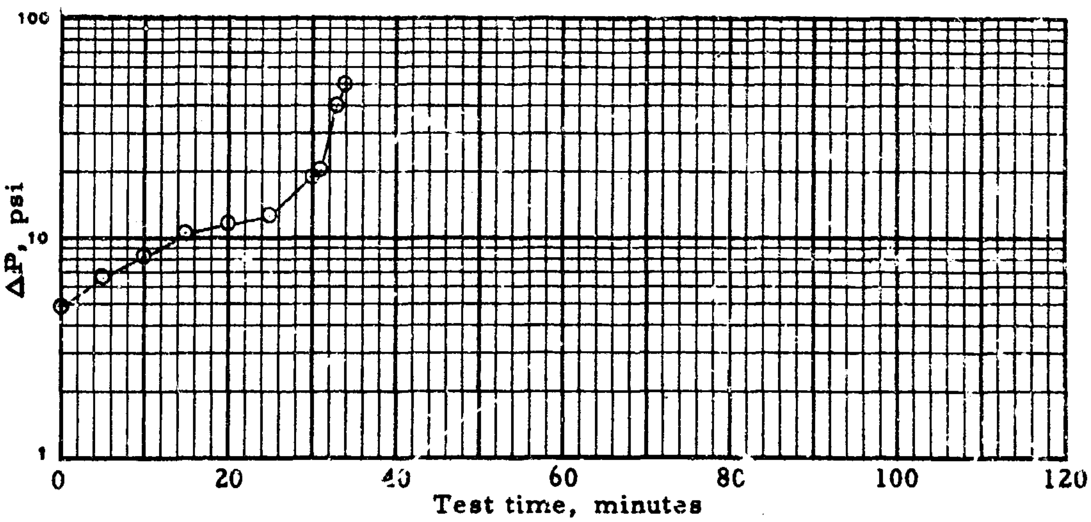


TABLE 154. SINGLE-ELEMENT LOOP TEST NO. 294
Date: 2 May 1969

Loop no. 3(Al/SS)		Housing:	8" I D Aluminum
		Element:	Bendix, 045800-04
		Canister:	DoD Type 1

Procedure no. 13-A	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 1 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541, Lot 24794

Test duration, min	36	Calculated dirt loading, g	143
Fuel throughput, gal	725	Actual element weight gain, g	158
Average rate, gpm	20.1		

Time	0 Min	End Test
Meter reading, gal	300	1025
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	37	45
IFT, distilled water, dyn/cm	44.8	25.4	26.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.5
pH	7.5
ST, dyn/cm	70.6

TABLE 154. SINGLE-ELEMENT LOOP TEST NO. 294 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.5	0	0			80
5	4.2	0	0	0.50	1-2	80
10	4.6	0	0			80
15	7.0	0	0			80
20	12.5	0	0			80
25	20.0	0	0	0.42	8-9	80
30	36.1	0	64	1.34	20+	80
35	39.1	0	100+		20+++	80
36	40.0	0	100+	1.15	20+++	80
38	41.3	0	100+			80
39	35.0	0	100+			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-25	0.002	5.72
25-36	0.2	----

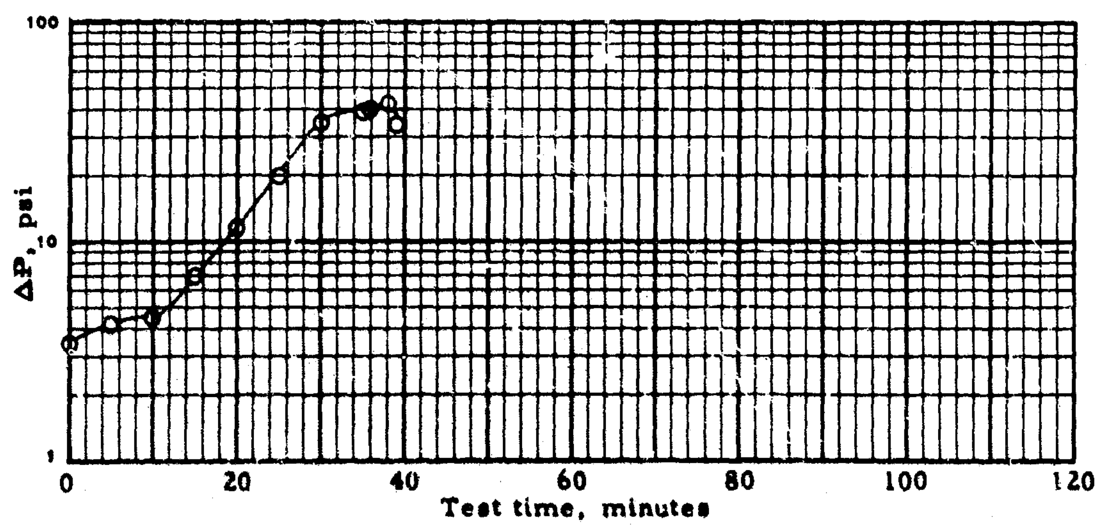


TABLE 155. SINGLE-ELEMENT LOOP TEST NO. 295
Date: 5 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Fram, Lot 14 DoD Type
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 5 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541, Lot 24794

Test duration, min 29
Fuel throughput, gal 565
Average rate, gpm 19.5

Calculated dirt loading, g 137
Actual element weight gain, g 99

Time	0 Min	End Test
Meter reading, gal	300	865
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	61	58
IFT, distilled water, dyn/cm	44.1	25.9	26.5

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.2
pH	7.4
ST, dyn/cm	69.6

TABLE 155. SINGLE-ELEMENT LOOP TEST NO. 295 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.0	0	0			80
5	5.0	0	0	0.52	5-6	80
10	5.9	0	0			80
15	9.0	0	0			80
20	14.5	0	0			80
24	20.0	0	0	0.62	15-16	80
29	40.0	0	100+	1.41	20+++	80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-24	0.002	5.72
24-29	0.2	----

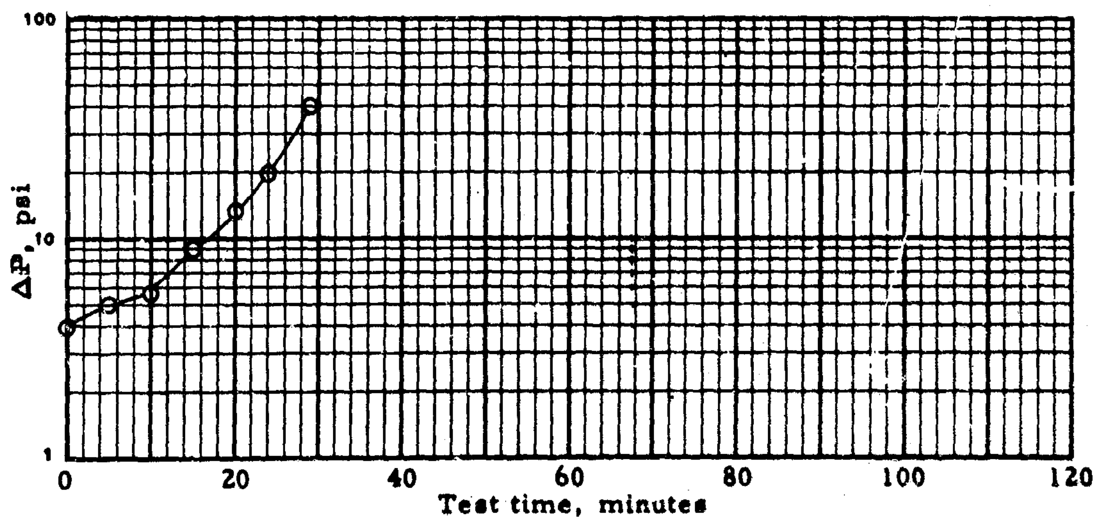


TABLE ... SINGLE-ELEMENT LOOP TEST NO. 296
Date: 5 May 1969

Loop no.	3(Al/SS)	**Housing:**	8" I D Aluminum
		Element:	Filter Inc, I4208 Lot 465
		Canister:	DoD Type 1

Procedure no.	13-A	**Fuel flow, gpm**	20
Water:	Filtered Tap Water	**Fuel inlet temperature, °F**	80
Solids:	Coarse AC Dust	**Fuel inlet pressure, psi**	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 **batch no.** 24 , reused, clay treated
Date blended with additives: 5 May 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor 20 **lb/Mbbl,** Lubrizol 541 **, Lot** 24794

Test duration, min	25	**Calculated dirt loading, g**	137
Fuel throughput, gal	506	**Actual element weight gain, g**	137
Average rate, gpm	20.2		

Time	0 Min	End Test
Meter reading, gal	300	806
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	63	----
IFT, distilled water, dyn/cm	41.8	25.2	25.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0
pH	7.6
ST, dyn/cm	68.0

TABLE 156. SINGLE-ELEMENT LOOP TEST NO. 296 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.2	0	0			80
5	3.6	0	0	0.20	20	80
10	3.6	0	0			80
15	4.2	0	0		7-8	80
20	6.1	0	0			80
24	20.0	0	0	1.04	19-20	80
25	40.0	0	0		20+++	80
26	48.5	0	100+			80
28	42.8	0	0			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-24	0.002	5.72
24-25	0.2	----

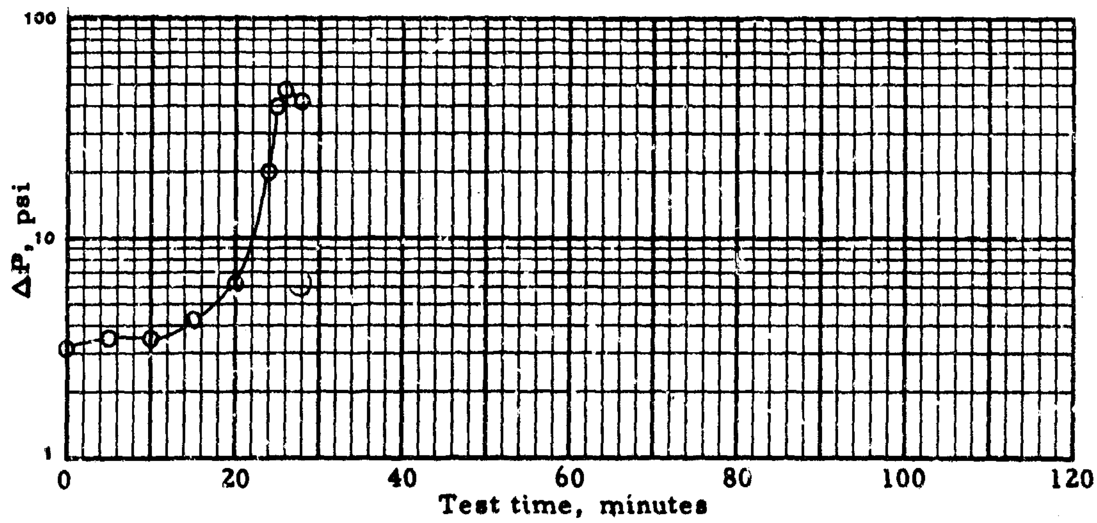


TABLE 157. SINGLE-ELEMENT LOOP TEST NO. 297
Date: 7 May 1969

Loop no.	3(A1/SS)	Housing:	8" I D Aluminum
		Element:	Bendix, Part No. 045800-04
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 6 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	30	Calculated dirt loading, g	114
Fuel throughput, gal	600	Actual element weight gain, g	126
Average rate, gpm	20.0		

Time	0 Min	End Test
Meter reading, gal	299	899
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	96	65	51
IFT, distilled water, dyn/cm	40.3	24.9	26.2

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.4
pH	7.8
ST, dyn/cm	70.8

TABLE 157. SINGLE-ELEMENT LOOP TEST NO. 297 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.6	0	0			80
5	4.1	0	0	0.66	0-1	80
10	5.1	0	0			80
15	9.5	0	0			80
20	20.0	0	0	5.98	4-5	80
25	36.0	0	45	0.94	20	80
30	40.0	0	100+	1.16	20+++	80
31	40.8	0	100+			80
32	35.0	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-20	0.002	5.72
	20-30	0.2	----

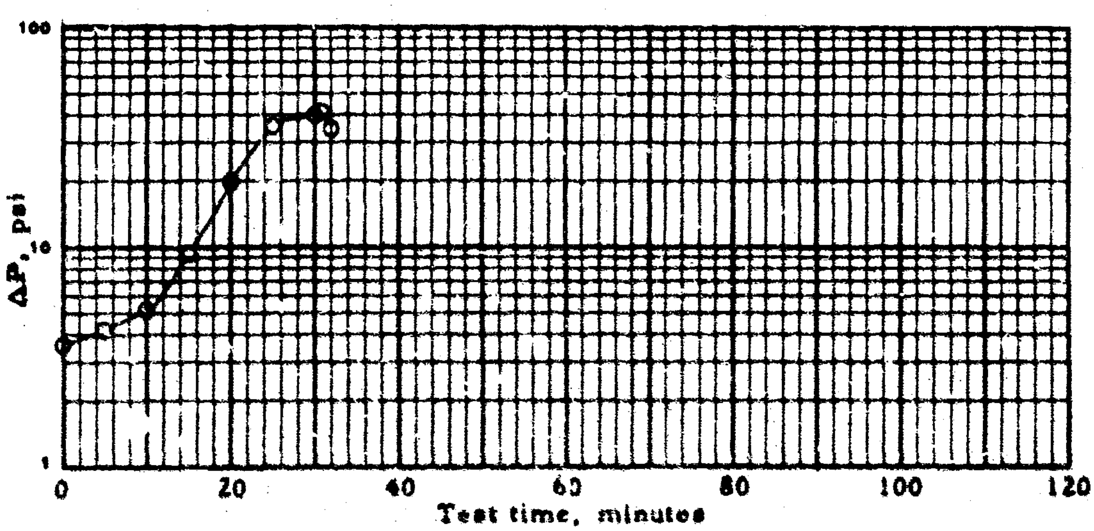


TABLE 158. SINGLE-ELEMENT LOOP TEST NO. 298
Date: 8 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Fram, Lot 14 DoD Type
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 7 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min 30
Fuel throughput, gal 590
Average rate, gpm 19.7

Calculated dirt loading, g 132
Actual element weight gain, g 123

Time	0 Min	End Test
Meter reading, gal	298	888
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	95	71	62
IFT, distilled water, dyn/cm	38.3	25.1	26.5

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	----
pH	7.8
ST, dyn/cm	72.0

TABLE 158. SINGLE-ELEMENT LOOP TEST NO. 298 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	0	0			80
5	4.9	0	0	0.47	0-1	80
10	5.5	0	0			80
15	9.2	0	0			80
20	14.7	0	0			80
23	20.0	0	0	0.63	16-17	80
28	37.2	0	100+	Neg	20+++	80
30	40.0	0	100+	1.29	20+++	80
30	41.0	0	100+			80
33	35.5	0	100+			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-23	0.002	5.72
23-30	0.2	----

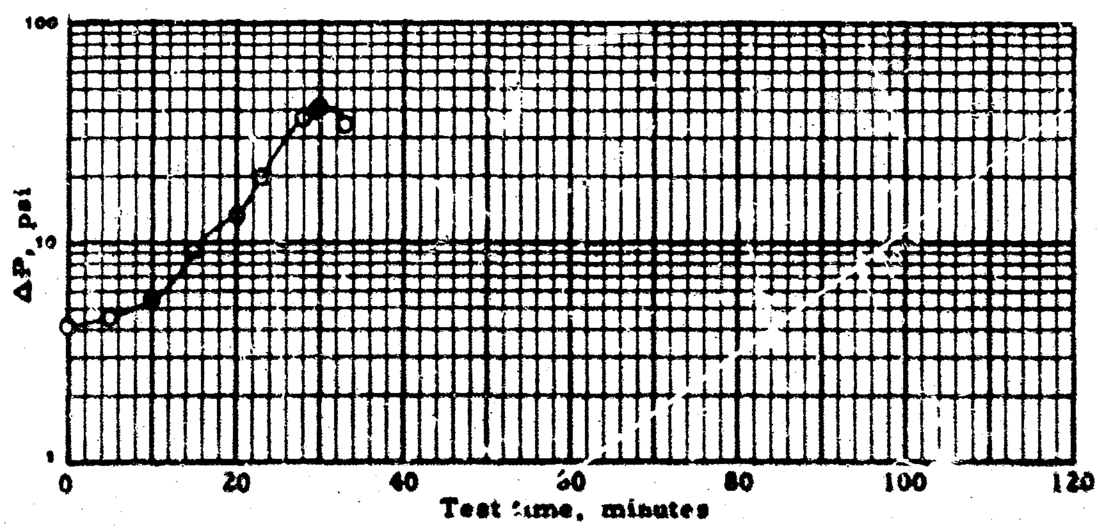


TABLE 159. SINGLE-ELEMENT LOOP TEST NO. 299
Date: 8 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Used Bowser, #2 (Andrews AFB)
Canister: DoD Type 1

Procedure no. Special
Water: Filtered Tap Water
Solids: None

Fuel flow, gpm Varied
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 to 30 min, 0.2 gpm from 30 to 45 min, 0.15 gpm from 45 to 55 min, 0.10 gpm from 55 to 66 min and then water off.

Solids injection schedule: None

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 8 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min 69
Fuel throughput, gal 1478
Average rate, gpm Varied

Calculated dirt loading, g
Actual element weight gain, g

Time	0 Min	End Test
Meter reading, gal	0	1478
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	92	95
IFT, distilled water, dyn/cm	37.0	37.0	34.0

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.1
pH	7.8
ST, dyn/cm	72.0

TABLE 159. SINGLE-ELEMENT LOOP TEST NO. 299 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	25.1	0	0		3-4	80
5	25.6	0	0		20+	80
10	25.6	0	20		20++	80
15	26.8	0	23		20++	80
20	26.9	0	23		20++	80
25	27.4	0	23		20++	80
30	28.2	0	23		20+++	80
35	30.3	0	100		20+++	80
40	31.6	0	100		---	80
45	29.5	0	100		---	80
50	23.0	0	100		---	80
55	23.0	0	80		---	80
60	14.5	0	10		20+++	80
65	14.5	0	10		20++	80
66	14.0	0	10		---	80
67	30.0	0	20		---	80
69	29.1	0	0		---	80

Schedule:

Minutes	Water, gpm	Solids, g/min	Fuel, gpm
0-30	0.002	0	20
30-45	0.2	0	20
45-55	0.15	0	15
55-66	0.10	0	10
66-69	0	0	20

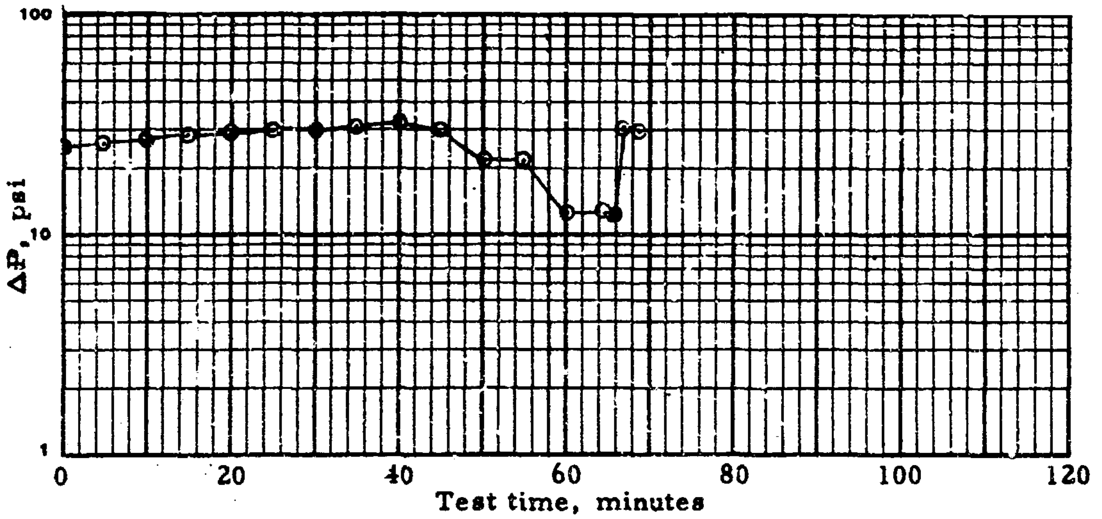


TABLE 160. SINGLE-ELEMENT LOOP TEST NO. 300A
Date: 15 May 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Bowser, Part No. A-1389-B, new
		Canister:	DoD Type 1

Procedure no.	Special	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	MIL-G-6032 grease (Royal Lubricants Co.)	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 60 to 90 min, then 0.2 gpm from 90 to 150 min.

Solids injection schedule: Approximately 0.51 g/min from 30 min to 60 min, then approximately 1.02 g/min from 120 min to 150 min.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 15 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	152	Calculated dirt loading, g	46
Fuel throughput, gal	3040[a]	Actual element weight gain, g	45
Average rate, gpm	20[a]		

Time	0 Min	End Test
Meter reading, gal	---	---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	98	95	95
IFT, distilled water, dyn/cm	44.7	45.7	45.3

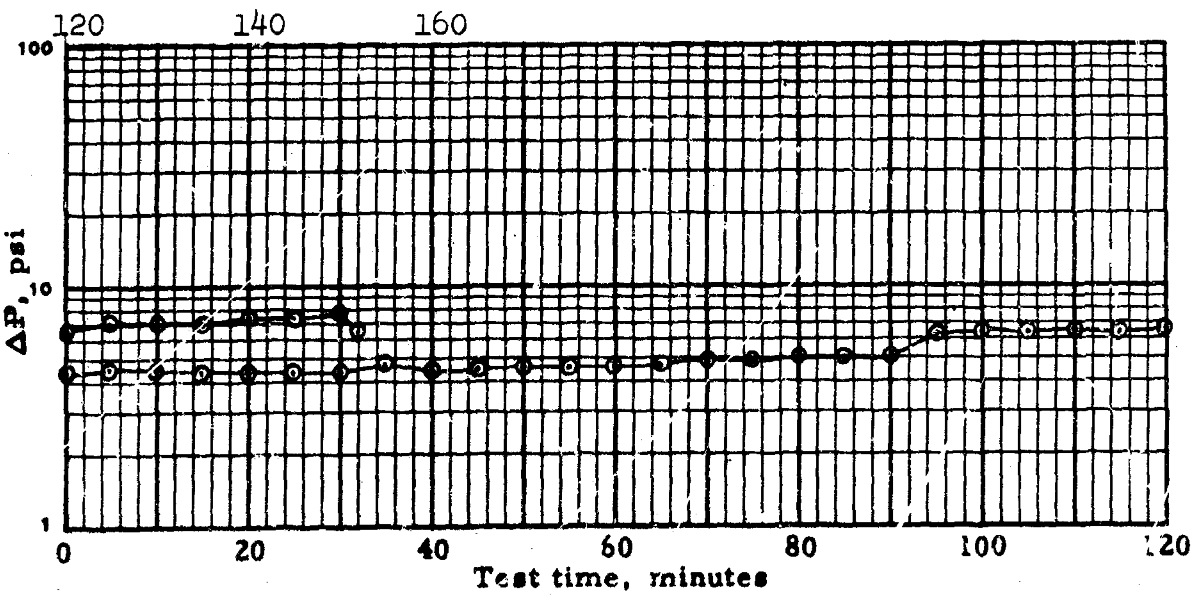
Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg.
pH	7.6
ST, dyn/cm	71.4

a. Approximate values; Brodie meter inoperative.

TABLE 160. SINGLE-ELEMENT LOOP TEST NO. 300A (Cont'd)

Schedule:	Minutes	Water, gpm	Solids, g/min
First period	0-30	0	0
	30-60	0	0.51[a]
	60-90	0.002	0
	90-120	0.2	0
	120-150	0.2	1.02[a]
	150-152	0	0



a. Approximate.

TABLE 160. SINGLE-ELEMENT LOOP TEST NO. 300A (Cont'd)

Time, min.	Fuel flow rate, gpm	Contaminant injection rate: Water gpm	Contaminant injection rate: Grease	ΔP, psi	Totamitor: Infl	Totamitor: Effl	Effluent, mg/liter: Solids	Effluent, mg/liter: Free Water	°F
0	20	0	0	4.4	0	0	---	---	80
5	20	0	0	4.6	0	0	a	0	80
10	20	0	0	4.5	0	0	---	0	80
15	20	0	0	4.4	0	0	---	---	80
20	20	0	0	4.4	0	0	---	---	80
25	20	0	0	4.4	0	0	---	---	80
30	20	0	b	4.4	0	0	---	---	80
35	20	0	b	4.8	0	0	0.83	0	80
40	20	0	b	4.4	0	0	---	---	80
45	20	0	b	4.5	0	0	---	---	80
50	20	0	b	4.6	0	0	---	---	80
55	20	0	b	4.6	0	0	---	---	80
60	20	0.002	b	4.6	0	0	---	---	80
65	20	0.002	b	4.7	0	0	0.99	4-5	80
70	20	0.002	b	4.9	0	0	---	3-4	80
75	20	0.002	b	4.9	0	0	---	---	80
80	20	0.002	b	5.0	0	0	---	---	80
85	20	0.002	b	5.0	0	0	---	---	80
90	20	0.2	b	5.0	0	0	---	3-4	80
95	20	0.2	b	6.2	0	0	0.71	4-5	80
100	20	0.2	b	6.3	0	0	---	4-5	80
105	20	0.2	b	6.2	0	0	---	---	80
110	20	0.2	b	6.4	0	0	---	3-4	80
115	20	0.2	b	6.3	0	0	---	---	80
120	20	0.2	c	6.5	0	0	---	2-3	80
125	20	0.2	c	7.0	0	0	0.73	7-8	80
130	20	0.2	c	7.0	0	0	---	6-7	80
135	20	0.2	c	7.0	0	0	---	---	80
140	20	0.2	c	7.4	0	0	---	2-3	80
145	20	0.2	c	7.4	0	0	---	---	80
150	20	0.2	0	7.8	0	0	0.70	6-7	80
152	20	0	0	6.5	---	---	---	---	80

a. Control pad damaged by operator - invalid results.
b. Approximately 15.3 gm injected during this period.
c. Approximately 30.6 gm injected during this period.

TABLE 161. SINGLE-ELEMENT LOOP TEST NO. 300B
Date: 16 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part No. A-1389-B [a]
Canister: DoD Type 1

Procedure no. Special
Water: Filtered Tap Water
Solids: None

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 30 to 60 min, first period and from 0 to 30 min of second period and 0.2 gpm from 60 to 90 min of second period.

Solids injection schedule: None

Test fuel JP-5 batch no. 24, reused
Date blended with additives: 16 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min 93 [b]
Fuel throughput, gal 1860 [b]
Average rate, gpm 20 [b]

Calculated dirt loading, g
Actual element weight gain, g

Time	0 Min	End Test
Meter reading, gal		
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	c	92	97
IFT, distilled water, dyn/cm	c	42.9	39.6

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.7
pH	7.8
ST, dyn/cm	70.6

a. Same element as used in Test 300A
b. Approximate values; Brodie meter inoperable.
c. No clay treatment performed.

TABLE 161. SINGLE-ELEMENT LOOP TEST NO. 300B (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.5	0	0		2-3	80
10	5.5	0	0	Neg	4-5	80
20	5.5	0	0		7-8	80
30	5.5	0	0		5-6	80
40	6.1	3	0	0.34	14-15	80
50	6.3	3	0		14-15	80
60	6.4	3	0		14-15	80
70	6.2	3	0	Neg	10-11	80
80	6.1	4	0		15-16	80
90	5.9	4	0		8-9	80
0	---	---	---		9-10	---
10	6.4	2	0	0.28	15-16	80
20	6.4	2	0		13-14	80
30	6.4	2	0		9-10	80
40	6.2	2	0		9-10	80
50	6.2	2	0		8-9	80
60	6.0	2	0		6-7	80
70	7.6	5	0		10-11	80
80	7.6	5	0		7-8	80
90	7.6	5	0		18-19	80
93	7.0	5	0		---	80

Schedule:	Minutes	Water, gpm	Solids, g/min
First period	0-30	0	0
	30-60	0.002	0
	60-90	0	0
Second period	0-30	0.002	0
	30-60	0	0
	60-90	0.2	0
	90-93	0	0

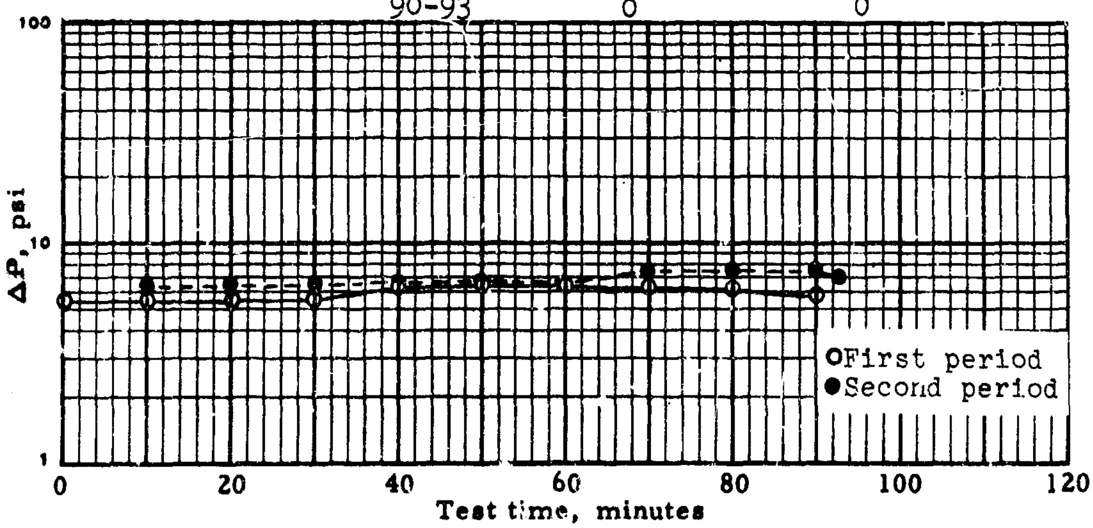


TABLE 162. SINGLE-ELEMENT LOOP TEST NO. 300C
Date: 19 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part No. A-1389-B[a]
Canister: DoD Type

Procedure no. Special
Water: Filtered Tap water
Solids: None

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.2 gpm from 150 to 180 min.

Solids injection schedule: None

Test fuel JP-5 batch no. 24, reused
Date blended with additives: 19 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	241
Fuel throughput, gal	4820[b]
Average rate, gpm	20[b]
Calculated dirt loading, g	
Actual element weight gain, g	

Time	0 Min	End Test
Meter reading, gal	---	---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	c	91	97
IFT, distilled water, dyn/cm	c	41.7	43.1

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	
ST, dyn/cm	71.5

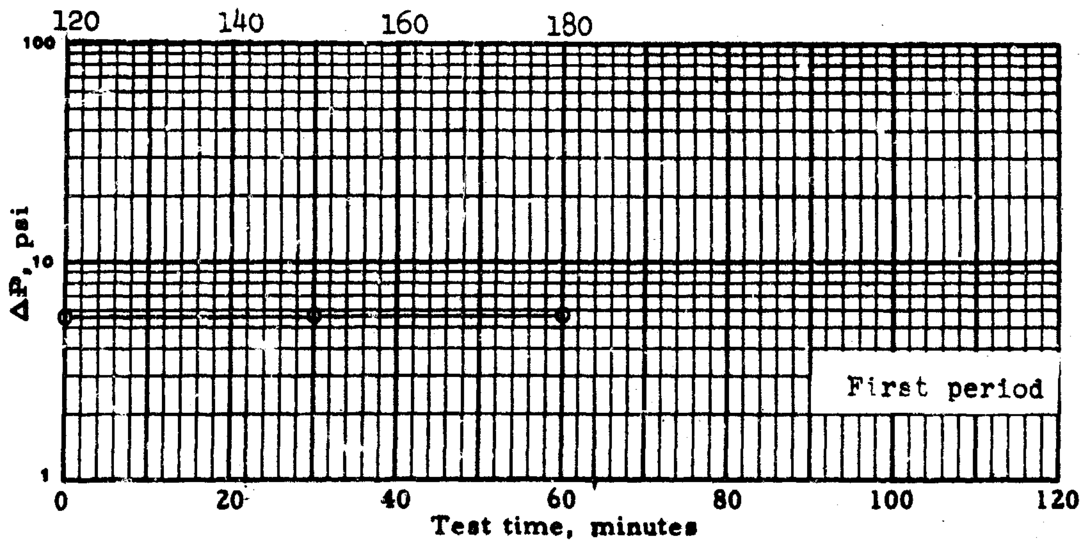
a. Same element as used in Tests 300A and 300B.
b. Approximate values; Brodie meter inoperable.
c. No clay treatment performed.

TABLE 162. SINGLE-ELEMENT LOOP TEST NO. 300C (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.6	0	0	---	---	80
30	5.7	0	0	0.13	10-11	80
60	5.7	0	0	---	9-10	80
0	---	---	---	---	---	---
30	5.6	0	0	---	15-16	80
60	5.6	8	0	---	10-11	80
90	5.6	3	0	---	7-8	80
120	5.6	4	0	---	9-10	80
150	5.6	3	0	---	9-10	80
155	7.3	3	0	---	13-14	80
160	7.4	3	0	---	14-15	80
165	7.4	3	0	0.08	10-11	80
170	7.5	3	0	---	10-11	80
175	7.5	3	0	---	11-12	80
180	7.8	3	0	---	11-12	80
181	7.0	3	0	---	---	80

TABLE 162. SINGLE-ELEMENT LOOP TEST NO. 300C (Cont'd)

Schedule:	Minutes	Water, gpm	Solids, g/min
First period	0-60	0	0
Second period	0-150	0	0
	150-180	0.2	0
	180-181	0	0



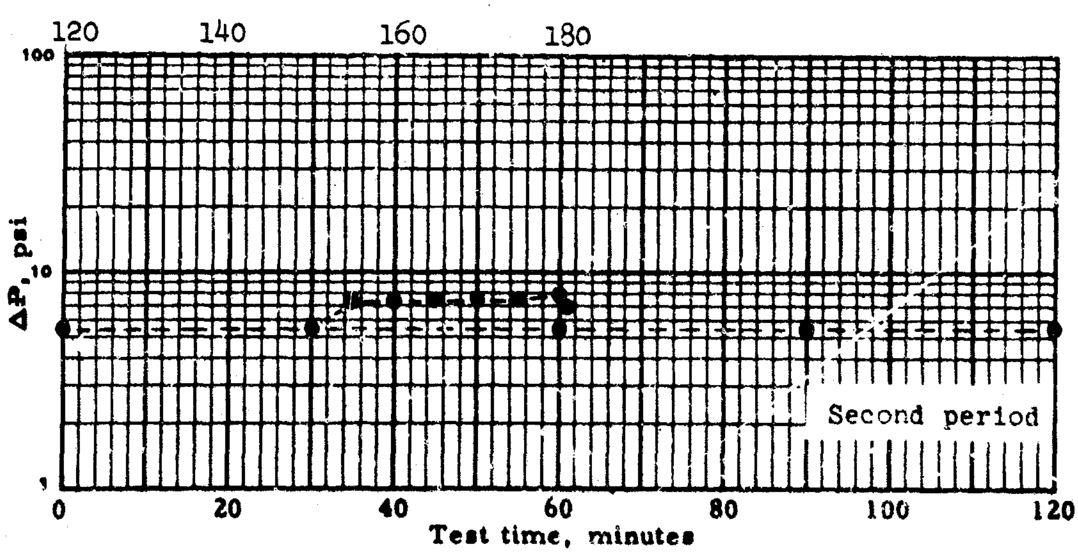


TABLE 163. SINGLE-ELEMENT LOOP TEST NO. 300D
Date: 20 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part No. A-1389-B[a]
Canister: DoD Type 1

Procedure no. Special
Water: Filtered Tap Water
Solids: None

Fuel flow, gpm Varied
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.2 gpm from 60 to 90 min.

Solids injection schedule: None

Test fuel JP-5 **batch no.** 24 **, reused**
Date blended with additives:
Anti-icing additive 0.04 **vol %, Dow, Lot**
Corrosion inhibitor None **lb/Mbbl, , Lot**

Test duration, min	92	Calculated dirt loading, g	
Fuel throughput, gal	2140[b]	Actual element weight gain, g	
Average rate, gpm	Varied		

Time	0 Min	End Test
Meter reading, gal		---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	c	91	98
IFT, distilled water, dyn/cm	c	43.4	43.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.5
ST, dyn/cm	72.0

a. Same element as used in Tests 300A, 300B, and 300C.
b. Approximate value; Brodie meter inoperable.
c. No clay treatment performed.

TABLE 163. SINGLE-ELEMENT LOOP TEST NO. 300D (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	6.5	0	0		---	80
5	10.8	0	0		---	80
10	10.8	0	0		---	80
15	10.8	0	0	0.10	11-12	80
20	10.5	0	0		---	80
25	10.4	0	0		---	80
30	10.3	0	0		13-14	80
35	6.2	0	0		---	80
40	6.1	3	0		---	80
45	6.1	4	0	Neg	9-10	80
50	6.1	5	0		---	80
55	6.1	5	0		---	80
60	6.1	5	0		7-8	80
65	7.4	4	0		18-19	80
70	7.6	4	0		---	80
75	7.6	4	0	0.15	6-7	80
80	7.6	4	0		---	80
85	7.6	4	0		17-18	80
90	7.8	4	0		7-8	80
92	6.9	0	0		---	

Schedule:

Minutes	Water, gpm	Solids, g/min	Fuel, gpm
0-30	0	0	30
30-60	0	0	20
60-90	0.2	0	20
90-92	0	0	20

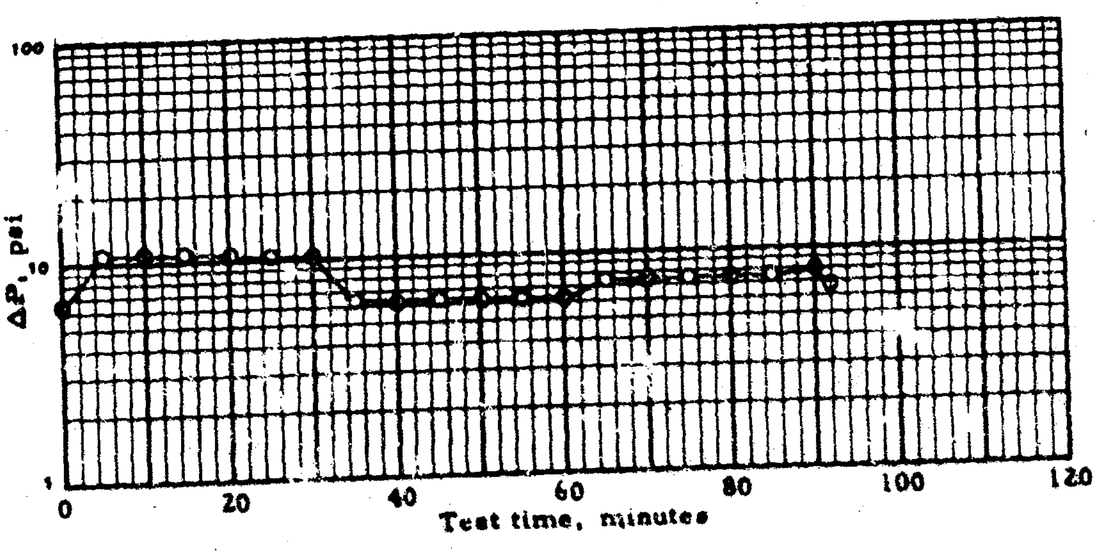


TABLE 164. SINGLE-ELEMENT LOOP TEST NO. 301
Date: 21 May 1969

Loop no.	3(AL/SS)	Housing:	8" I D Aluminum
		Element:	Bowser, Part A-1389-B[a]
		Canister:	DoD Type 1
Procedure no.	Special	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Walworth No. 1 plug valve sealant	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 60 to 90 min, 0.2 gpm from 90 to 105 min.

Solids injection schedule: Approximately 57 gm injected during period from 30 to 60 min.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 21 May 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	106	Calculated dirt loading, g	57
Fuel throughput, gal	2120[b]	Actual element weight gain, g	48
Average rate, gpm	20[b]		

Time	0 Min	End Test
Meter reading, gal	---	---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	95	96
IFT, distilled water, dyn/cm	46.3	46.3	43.3

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.5
ST, dyn/cm	69.5

a. Used element from Andrews AFB. Element had been soaked in isopropanol for over 24 hours and then dried before test.
b. Approximate values; Brodie meter inoperable.

TABLE 164. SINGLE-ELEMENT LOOP TEST NO. 301 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	6.2	0	0		0	80
15	6.5	0	0		0	80
30	6.5	0	0		0	80
45	6.5	0	0	Neg	0-1	80
60	6.5	0	0		0	80
75	6.9	0	5		20+	80
90	7.1	0	5		20+	80
95	8.3	0	30		20+++	80
100	8.8	0	30		20+++	80
105	8.9	0	30		20+++	80
106	8.5	0	7		---	80

Schedule:	Minutes	Water, gpm	Solids, g/min	Fuel, gpm
	0-30	0	0	20
	30-60	0	1.9[a]	20
	60-90	0.002	0	20
	90-105	0.2	0	20
	105-106	0	0	20

a. Approximate

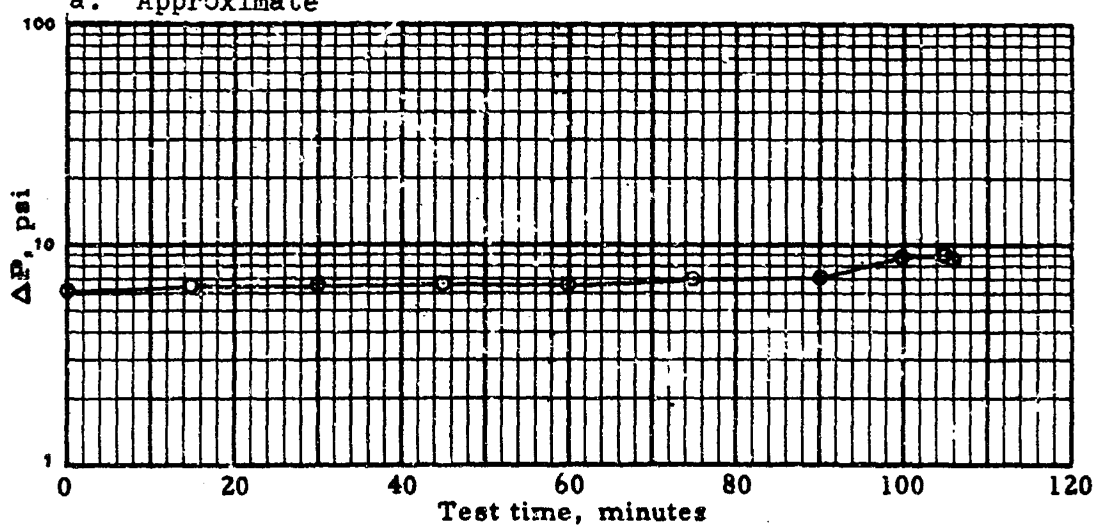


TABLE 165. SINGLE-ELEMENT LOOP TEST NO. 302
Date: 22 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, Part. No. A-1389-B
Canister: DoD Type 1

Procedure no. Special
Water: Filtered Tap Water
Solids: Walworth No. 1 Plug valve sealant.

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 60 to 90 min, 0.2 gpm from 90 to 120 min.

Solids injection schedule: Approximately 75 gm injected during period from 30 to 60 min.

Test fuel JP-5 **batch no.** 24 , reused
Date blended with additives: 22 May 1969
Anti-icing additive 0.15 **vol %, Dow, Lot** 02268 16
Corrosion inhibitor None **lb/Mbbl,** **, Lot**

Test duration, min 121
Fuel throughput, gal 2420[a]
Average rate, gpm 20[a]

Calculated dirt loading, g 75
Actual element weight gain, g 110

Time	0 Min	End Test
Meter reading, gal	---	---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	b	92	93
IFT, distilled water, dyn/cm	b	42.3	38.5

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.9
pH	
ST, dyn/cm	71.6

a. Approximate value; Brodie meter inoperable.
b. No clay treatment performed.

TABLE 165. SINGLE-ELEMENT LOOP TEST NO. 302 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.5	0	0		0	80
15	4.5	0	0		0	80
30	4.5	0	0		0	80
45	4.5	0	0	Neg	0	80
60	4.5	0	0		0	80
75	4.6	0	0		3-4	80
90	4.9	0	0		3-4	80
95	5.1	0	0		3-4	80
105	6.1	0	0	0.14	3-4	80
120	6.1	0	0		3-4	80
121	5.6	0	0			80

Schedule:

Minutes	Water, gpm	Solids, g/min	Fuel, gpm
0-30	0	0	20
30-60	0	2.5[a]	20
60-90	0.002	0	20
90-120	0.2	0	20
120-121	0	0	20

a. Approximate

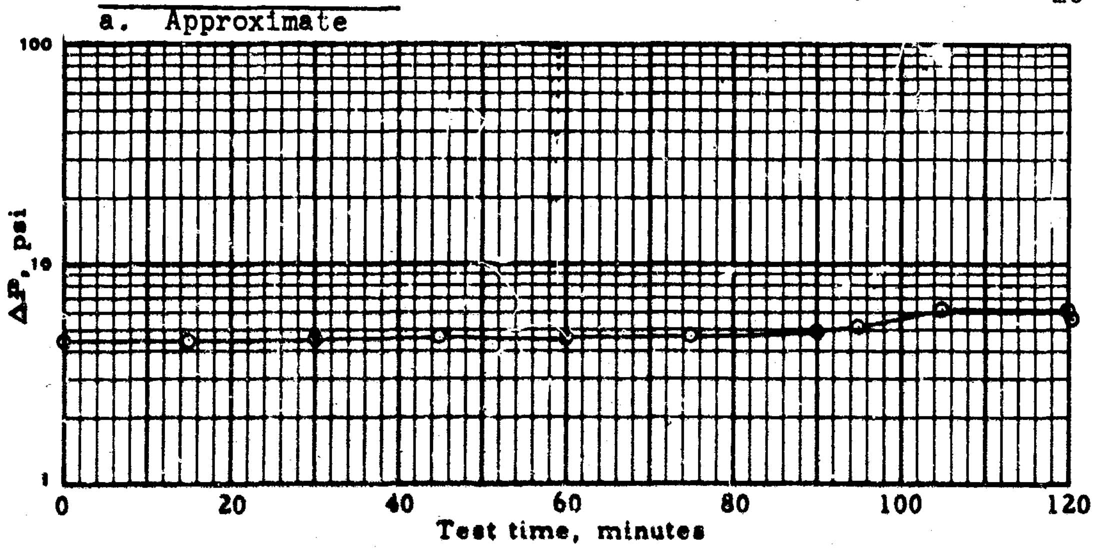


TABLE 166. SINGLE-ELEMENT LOOP TEST NO. 303A
Date: 23 May 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, A-1389-B
Canister: DoD Type 1

Procedure no. Special
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 105 to 135 min, 0.2 gpm from 135 min to 165 min.

Solids injection schedule:[a] 5.72 g/min from 65 to 70 min.

Test fuel JP-5 batch no. 24, reused
Date blended with additives:
Anti-icing additive None vol %, Dow, Lot
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	226
Fuel throughput, gal	4520[b]
Average rate, gpm	20[b]

Calculated dirt loading, g
Actual element weight gain, g

Time	0 Min	End Test
Meter reading, gal	---	---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	c	90	97
IFT, distilled water, dyn/cm	c	38.0	37.2

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	---
ST, dyn/cm	71.7

a. Glycerol was also injected at a rate of 66 ml/min during the period from 15 to 75 min.
b. Approximate values; Brodie meter inoperable.
c. No clay treatment performed.

TABLE 166. SINGLE-ELEMENT LOOP TEST NO. 303 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.3	0	0			80
5	4.2	0	0		0-1	80
10	4.2	0	0	0.14		80
15	4.2	0	0		0-1	80
20	4.8	a	0			80
30	8.4	a	0		0	80
40	10.5	a	0			80
45	11.5	a	0	0.65	0	80
60	12.5	5	0		0	80
65	12.1	a	0			80
70	15.1	a	0	0.73	0	80
75	19.2	a	0		0	80
80	12.4	a	0			80
90	10.6	0	0			80
105	9.5	0	0		0	80
120	9.8	0	0		0	80
135	9.8	0	0		0-1	80
140	10.5	0	0		4-5	80
150	10.6	0	0	0.09	5-6	80
165	10.2	0	0			80
166	9.2	0	0			80
0	---		0			80
10	7.3	0	0			80
20	6.4	0	0			80
30	5.9	0	0			80
40	5.7	0	0			80
50	5.6	0	0			80
60	5.4	0	0			80

Schedule:	Minutes	Water, gpm	Solids, g/min	Fuel, gpm
First period	0-15	0	0	20
	15-65	0	b	20
	65-70	0	5.72[b]	20
	70-75	0	b	20
	75-105	0	0	20
	105-135	0.002	0	20
	135-165	0.2	0	20
	165-166	0	0	20
Second period	0-60	0	0	20

a. No reading taken; Totamitor downstream from glycerin injection port.

b. Glycerol injected at 66 ml/min.

TABLE 166. SINGLE-ELEMENT LOOP TEST NO. 303A(Cont'd)

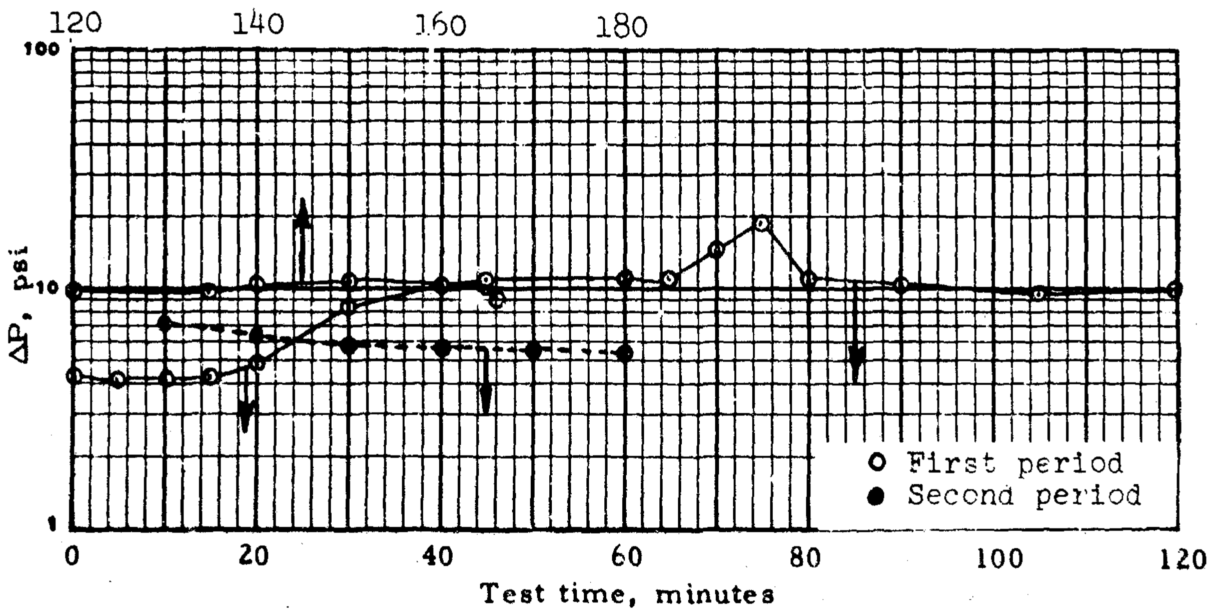


TABLE 167. SINGLE-ELEMENT LOOP TEST NO. 303B
Date: 27 May 1968

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Bowser, A-1389-B[a]
Canister: DoD Type 1

Procedure no. Special
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.2 gpm from 30 to 60 min of second period.

Solids injection schedule:[b] 5.72 g/min from 30 to 75 min of first period and from 0 to 10 min of second period.

Test fuel JP-5 batch no. 24 , reused
Date blended with additives:
Anti-icing additive None vol %, Dow, Lot
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min 135
Fuel throughput, gal 2700[c]
Average rate, gpm 20[c]

Calculated dirt loading, g 314
Actual element weight gain, g

Time	0 Min	End Test
Meter reading, gal	---	---
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	d	97	95
IFT, distilled water, dyn/cm	d	39.8	40.1

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.30
pH	---
ST, dyn/cm	72.4

a. Same element as used in Test 303A.
b. Glycerol was also injected at a rate of 133 ml/min from 25 to 30 min of second period.
c. Approximate values; Brodie meter inoperable.
d. No clay treatment performed.

TABLE 167. SINGLE-ELEMENT LOOP TEST NO. 303B (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.5	0	0		0-1	80
15	5.6	0	0	0.03	0-1	80
30	5.5	0	0		0-1	80
35	5.5	0	0		---	80
40	6.4	0	0		---	80
45	7.9	0	0		0-1	80
50	9.1	0	0		---	80
55	10.0	0	0		---	80
60	10.8	0	0		---	80
65	12.0	0	0		---	80
70	13.0	0	0		---	80
75	14.6	0	0		---	80
0	---	---	0		---	80
5	16.5	0	0		---	80
10	20.0	2	0	0.16	0-1	78
15	21.1	0	0		---	80
20	21.4	0	0		---	78
25	20.9	7	0		---	80
30	25.5	7	0		1-2	80
35	24.4	1	0		---	80
40	23.4	0	0		---	78
45	24.6	0	0	0.10	5-6	78
50	24.6	0	0		---	80
55	24.6	0	0		---	80
60	24.6	0	0		6-7	80

TABLE 167. SINGLE-ELEMENT LOOP TEST NO. 303B (Cont'd)

Schedule:	Minutes	Water, gpm	Solids, g/min
First period	0-30	0	0
	30-75	0	5.72
Second period	0-10	0	5.72
	10-25	0	0
	25-30	0	a
	30-60	0.2	0

a. Glycerol injected at a rate of 133 ml/min.

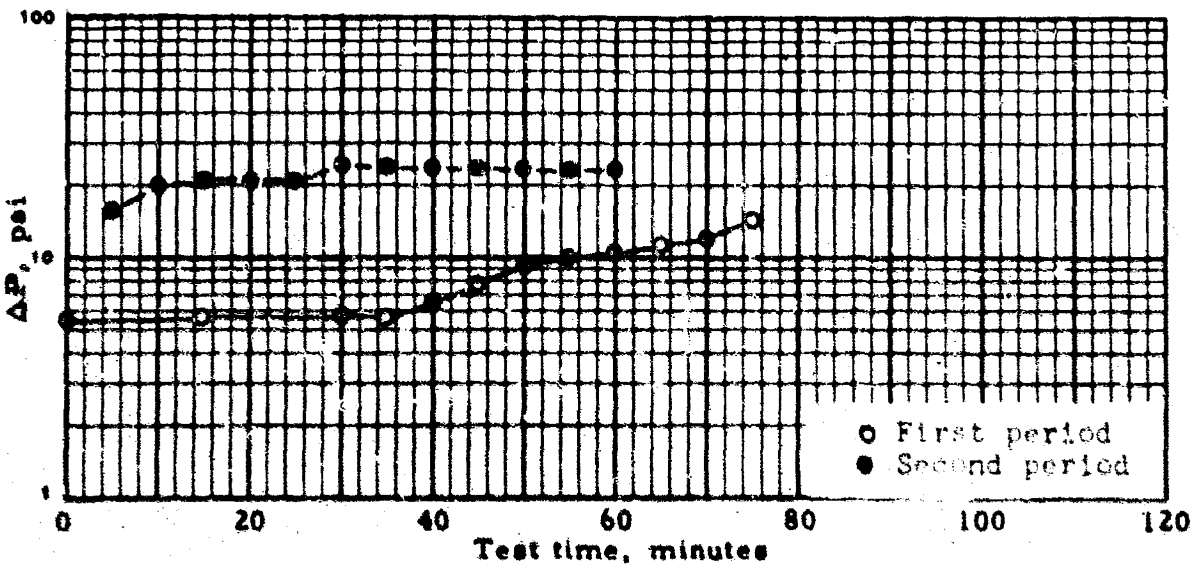


TABLE 168. SINGLE-ELEMENT LOOP TEST NO. 304
Date: 11 June 1969

Loop no. 3 (Al/SS)

Housing: 8" I.D. Aluminum
Element: Filters Inc, I-4208 Lot 465
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min; then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , fresh, clay treated
Date blended with additives: 11 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min 31
Fuel throughput, gal 619
Average rate, gpm 19.9

Calculated dirt loading, g 172
Actual element weight gain, g 162

Time	0 min	End Test
Meter reading, gal	303	922
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	100	46	54
IFT, distilled water, dyn/cm	48.6	26.5	26.5

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.1
pH	7.3
ST, dyn/cm	71.7

TABLE 168. SINGLE-ELEMENT LOOP TEST NO. 304 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.0	0	0			80
5	3.1	0	0	Neg	19-20	80
10	3.1	0	0			80
15	3.5	0	0			80
20	4.0	0	0			80
25	5.1	0	0			80
30	20.0	0	0	Neg	20+++	80
31	40.0	0	72	1.10	20+++	80

Totamitor peaked at 100+ after 40 psi.

Schedule:

Minutes	Water, gpm	Solids, g/min
0-30	0.002	5.72
30-31	0.2	----

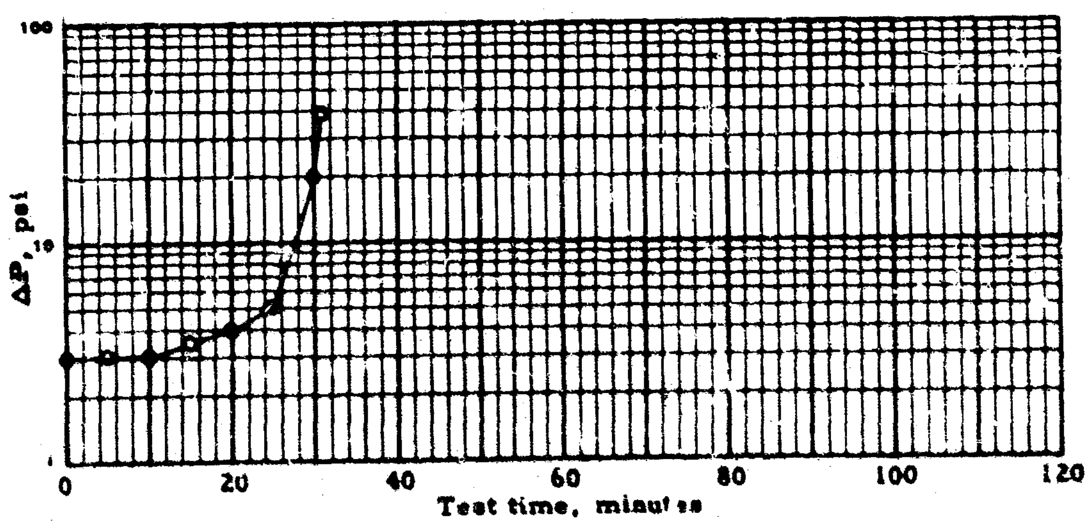


TABLE 169. SINGLE-ELEMENT LOOP TEST NO. 305
Date: 12 June 1969

Loop no. 3(Al/SS)

Housing: 8"I D Aluminum
Element: Bowser, Part No. A-1389-B
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm	20
Fuel inlet temperature, °F	80
Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 12 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min 45
Fuel throughput, gal 889
Average rate, gpm 19.8

Calculated dirt loading, g 234
Actual element weight gain, g 223

Time	0 min	End Test
Meter reading, gal	301	1190
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	96	65	68
IFT, distilled water, dyn/cm	45.5	24.9	25.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	71.7
ST, dyn/cm	7.5

TABLE 169. SINGLE-ELEMENT LOOP TEST NO. 305 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	0	0			80
5	4.5	0	0	Neg	17-18	80
10	5.0	0	1			80
12	6.0	0	2		18-20	80
15	6.7	0	1			80
20	7.9	0	0			80
21	8.3	0	0		17-18	80
25	9.5	0	0		16-17	80
30	10.5	0	0			80
35	12.6	0	0			80
40	19.0	0	0			80
41	20.0	0	1	Neg	19-20	80
45	40.0	0	100+	0.54		80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-41	0.002	5.72
41-45	0.2	----

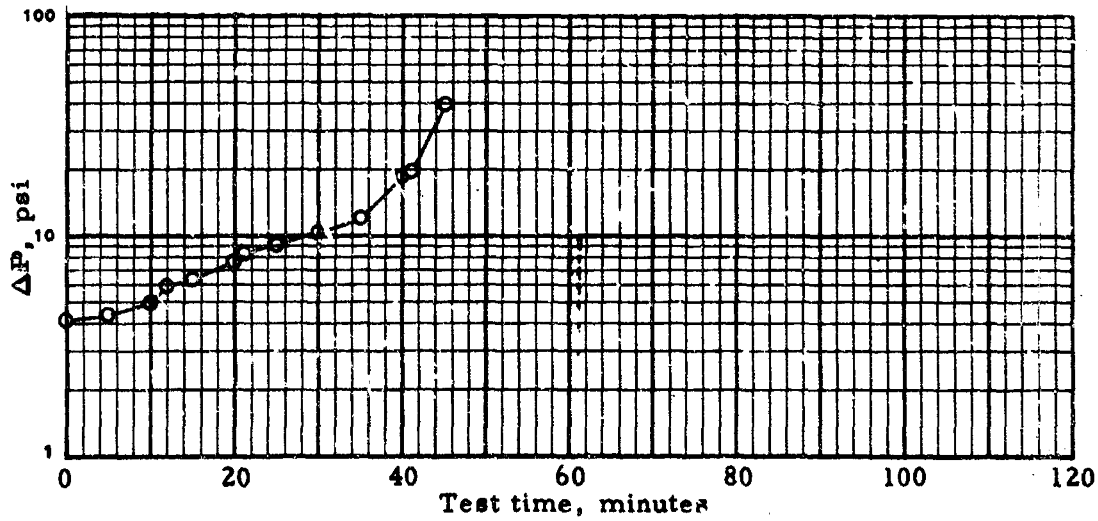


TABLE 170. SINGLE-ELEMENT LOOP TEST NO. 306
Date: 16 June 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Bendix, Part No. 045800-04
		Canister:	DoD Type 1
Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 16 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541, Lot 24794

Test duration, min	34	Calculated dirt loading, g	160
Fuel throughput, gal	679	Actual element weight gain, g	161
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	306	985
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:	Post Clay Filter	Pre-test	Post-test
Time			
WSIM, distilled water	98	72	60
IFT, distilled water, dyn/cm	47.4	26.2	27.5

Analyses on injection water:	
Time	Post-test
Solids, mg/liter	Neg
pH	7.5
ST, dyn/cm	70.9

TABLE 170. SINGLE-ELEMENT LOOP TEST NO. 306 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.5	0	0			80
5	3.8	0	2	0.06	3-4	80
7	3.9	0	1			80
10	4.3	0	1		5-6	80
15	5.6	0	0			80
20	9.5	0	0			80
25	15.2	0	0			80
28	20.0	0	0	Neg	10-11	80
33	39.4	0	38	0.60	20+	80
34	40.0	0	44	0.70	20+	80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-28	0.002	5.72
	28-34	0.2	---

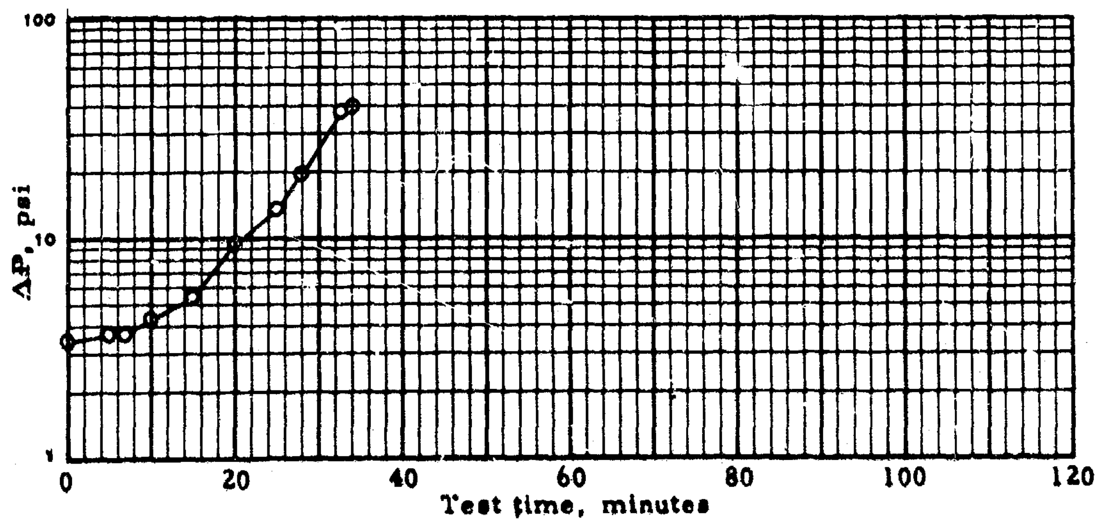


TABLE 171. SINGLE-ELEMENT LOOP TEST NO. 307
Date: 17 June 1969

Loop no.	3 (Al/SS)	Housing:	8" I D Aluminum
		Element:	Fram, Lot 14 DoD Type
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 16 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	32	Calculated dirt loading, g	149
Fuel throughput, gal	640	Actual element weight gain, g	128
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	940
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	98	54	66
IFT, distilled water, dyn/cm	45.1	25.6	26.0

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.4
pH	7.8
ST, dyn/cm	71.1

TABLE 171. SINGLE-ELEMENT LOOP TEST NO. 307 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	8[a]	0			80
5	4.8	6	1	0.12	10-11	80
10	5.5	3	1			80
15	8.2	2	0		10-11	80
20	12.5	1	1			80
25	17.7	1	2			80
26	20.0	1	2	0.53	20+	80
31	37.8	1	100+	0.58	20+++	80
32	40.0	1	100+	1.14	20+++	80
33	44.2	1	100+			80
36	34.3	1	100+			80

a. Influent Totamitor readings of doubtful accuracy due to omission of usual calibration procedure.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-26	0.002	5.72
	26-32	0.2	---

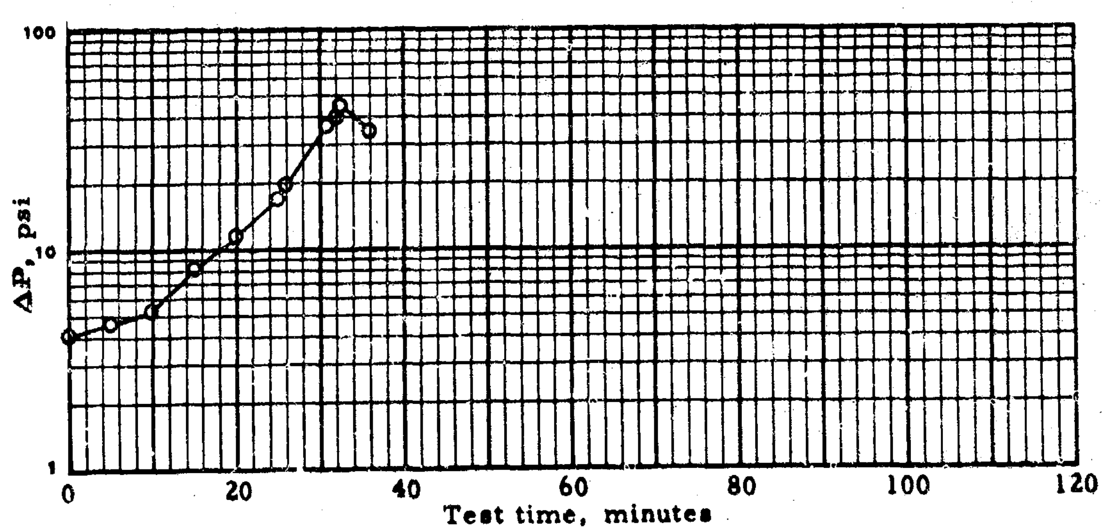


TABLE 172. SINGLE-ELEMENT LOOP TEST NO. 308
Date: 18 June 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Filters Inc, I-4208 Lot 465
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 17 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	37	Calculated dirt loading, g	210
Fuel throughput, gal	745	Actual element weight gain, g	206
Average rate, gpm	20.1		

Time	0 min	End Test
Meter reading, gal	397	1142
Screen ΔP, psi	2	2
Cleanup ΔP, psi	2	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	96	78	68
IFT, distilled water, dyn/cm	44.1	26.0	26.0

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.0
pH	7.8
ST, dyn/cm	71.1

TABLE 172. SINGLE-ELEMENT LOOP TEST NO. 308 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.4	0	0	Neg	17-18	80
5	3.5	0	0		7- 8	80
10	4.1	0	0			80
15	4.3	0	0			80
20	4.7	0	0			80
25	5.3	0	0			80
30	7.1	0	0			80
35	9.5	0	0	0.31	15-16	80
36.75	20.0	0	0			80
37	40.0	0	0			80
38	50+	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-36.75	0.002	5.72
	36.75-38	0.2	---

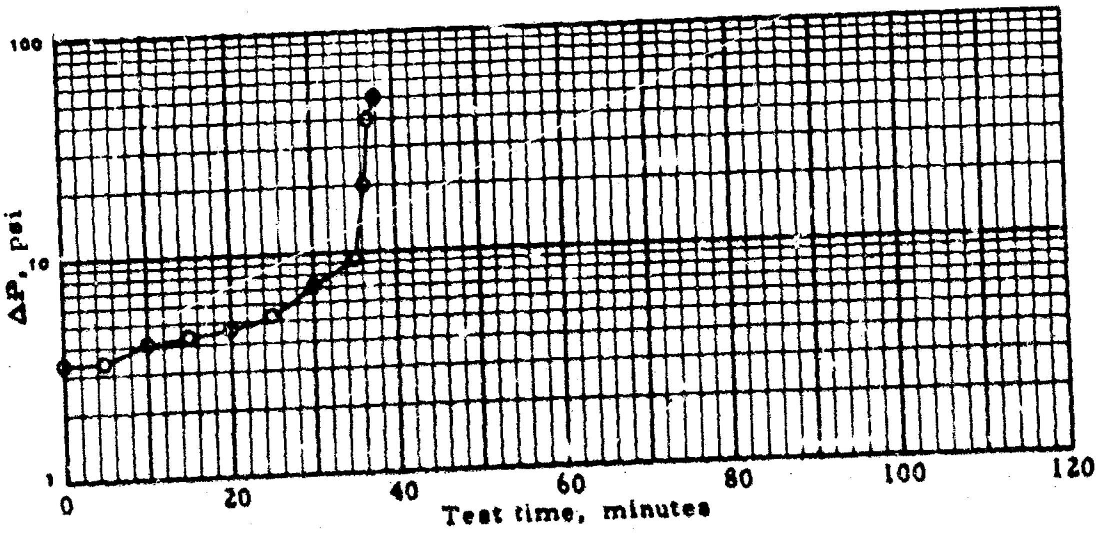


TABLE 173. SINGLE-ELEMENT LOOP TEST NO. 309
Date: 19 June 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Bowser, Part No. A-1389-B
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 18 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	46	Calculated dirt loading, g	200
Fuel throughput, gal	914	Actual element weight gain, g	194
Average rate, gpm	19.8		

Time	0 min	End Test
Meter reading, gal	299	1213
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	97	72	71
IFT, distilled water, dyn/cm	43.4	25.4	26.5

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.3
pH	7.5
ST, dyn/cm	71.8

TABLE 173. SINGLE-ELEMENT LOOP TEST NO. 309 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.7	0	0			80
5	5.4	0	0	Neg	7- 8	80
10	7.2	0	0			80
15	8.4	0	0			80
20	10.7	0	0			80
25	11.7	0	0			80
30	15.0	0	0			80
35	20.0	0	0	0.05	18-19	80
40	28.7	0	100+	0.81	20+++	80
45	38.0	0	100+		20+++	80
45.5	40.0	0	100+	0.72	20+++	80
46	40.5	0	100+			80
49	35.0	0	100+			

Schedule:

Minutes	Water, gpm	Solids, g/min
0-35	0.002	5.72
35-45.5	0.2	---

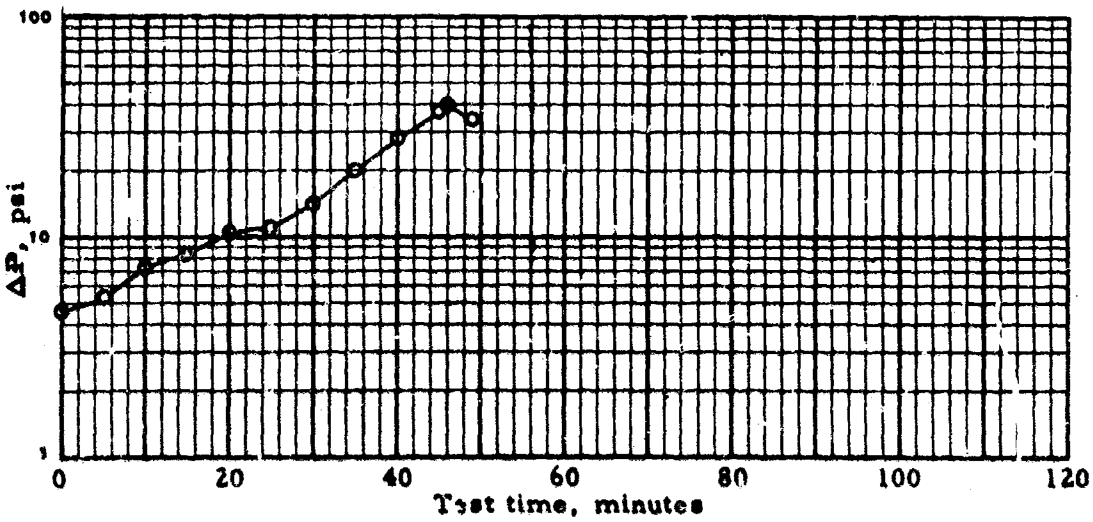


TABLE 174. SINGLE-ELEMENT LOOP TEST NO. 310
Date: 23 June 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Filters Inc [a]
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 23 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	39	Calculated dirt loading, g	217
Fuel throughput, gal	775	Actual element weight gain, g	210
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	300	1075
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	98	78	75
IFT, distilled water, dyn/cm	39.4	25.8	26.7

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.9
pH	7.7
ST, dyn/cm	70.8

a. Government Standard Elements DSA 700-68-C-B526, Filters Inc, Part No. I-4208, manufactured 10-68.

TABLE 174. SINGLE-ELEMENT LOOP TEST NO. 310 (Cont'd)

Time, min	ΔP, psi	Totamitor		Effluent, mg/liter		Influent fuel temperature, °F
		Infl	Effl	Solids	Free water	
0	5.0	0	0	Neg	17-18	80
5	5.5	0	0		10-11	80
10	5.4	0	0			80
15	5.6	0	0			80
20	6.4	0	0			80
25	7.3	0	0			80
30	8.6	0	0			80
35	12.9	0	0			80
38	20.0	0	0	1.44	16-17	80
39	40.0	0	0	Neg	20+	80
40	50+	0	1			80
43	48.3	0	0			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-38	0.002	5.72
	38-39	0.2	---

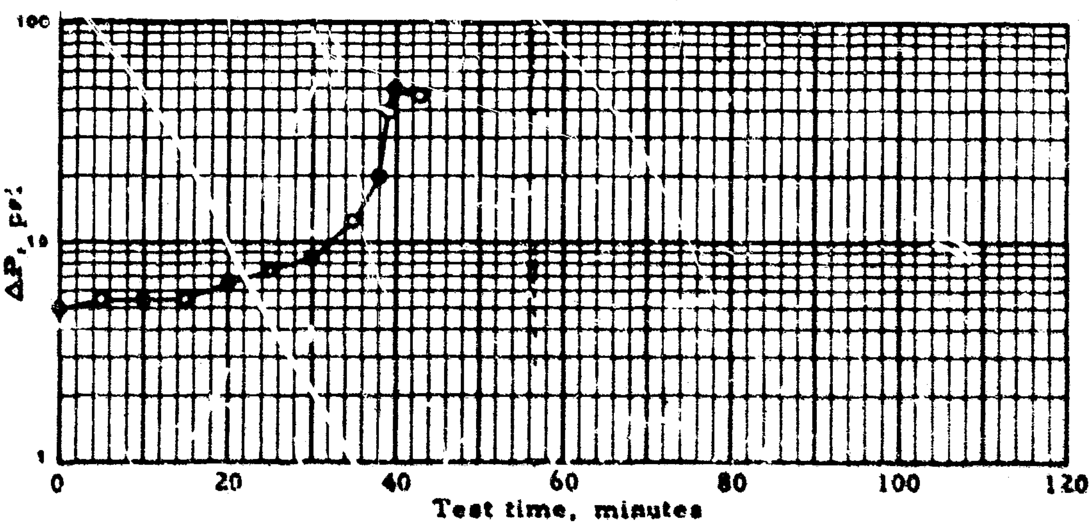


TABLE 175. SINGLE-ELEMENT LOOP TEST NO. 311
Date: 24 June 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum[a]
Element: Filters Inc
Canister: DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 23 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541, Lot 24794

Test duration, min	33	Calculated dirt loading, g	183
Fuel throughput, gal	660	Actual element weight gain, g	184
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading,	300	960
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	99	79	73
IFT, distilled water, dyn/cm	34.7	22.9	23.8

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.0
pH	7.7
ST, dyn/cm	70.6

a. Government Standard Elements, DSA 700-68-C-B526, Filters Inc, Part No. I-4208, manufactured 10-68.

TABLE 175. SINGLE-ELEMENT LOOP TEST NO. 311 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.4	0	0			80
5	4.5	0	0	0.22	10-11	80
10	4.8	0	0			80
15	5.2	0	0			80
20	5.9	0	0			80
25	7.5	0	0			80
30	13.6	0	0			80
32	20.0	0	0	1.17	20+	80
33	40.0	0	40	Neg	20+++	80
34	47.5	0	75			80
37	47.5	0	1			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-32	0.002	5.72
32-33	0.2	----

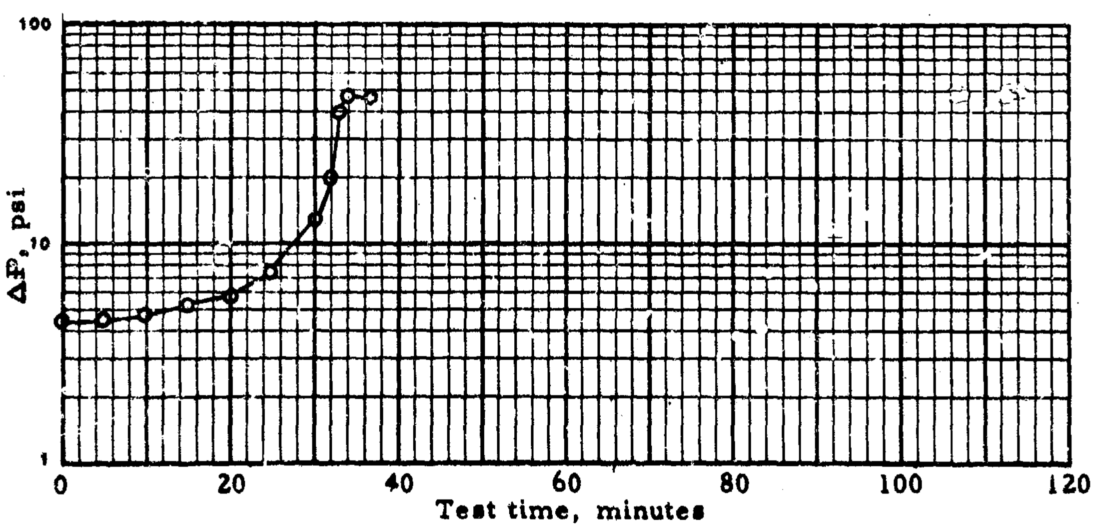


TABLE 176. SINGLE-ELEMENT LOOP TEST NO. 312
Date: 25 June 1969

Loop no. 3(Al/SS)

Housing: 8" I D Aluminum
Element: Filters Inc[a]
Canister: DoD Type 1

Procedure no. 13-A
Water: Filtered Tap Water
Solids: Coarse AC Dust

Fuel flow, gpm 20
Fuel inlet temperature, °F 80
Fuel inlet pressure, psi 70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 24 June 1969
Anti-icing additive 0.15 vol %, Dow, Lot 02268 16
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541, Lot 24794

Test duration, min 38
Fuel throughput, gal 760
Average rate, gpm 20.0

Calculated dirt loading, g 212
Actual element weight gain, g 209

Time	0 min	End Test
Meter reading, gal	299	1059
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	2

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	96	72	84
IFT, distilled water, dyn/cm	34.3	23.4	24.0

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.2
pH	7.7
ST, dyn/cm	70.8

a. Government standard elements, DSA 700-68-C-B526, Filters Inc, part No. I-4208, manufactured 10-68.

TABLE 176. SINGLE-ELEMENT LOOP TEST NO. 312 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.7	0	0			80
5	4.8	0	0	Neg	5- 6	80
10	5.2	0	0			80
15	5.5	0	0			80
20	6.2	0	0			80
25	8.0	0	0			80
30	11.1	0	0			80
35	17.5	0	0			80
37	20.0	0	0	Neg	19-20	80
38	40.0	0	8	Neg	20+	80
39	47.0	0	17			80
42	47.0	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-37	0.002	5.72
	37-38	0.2	---

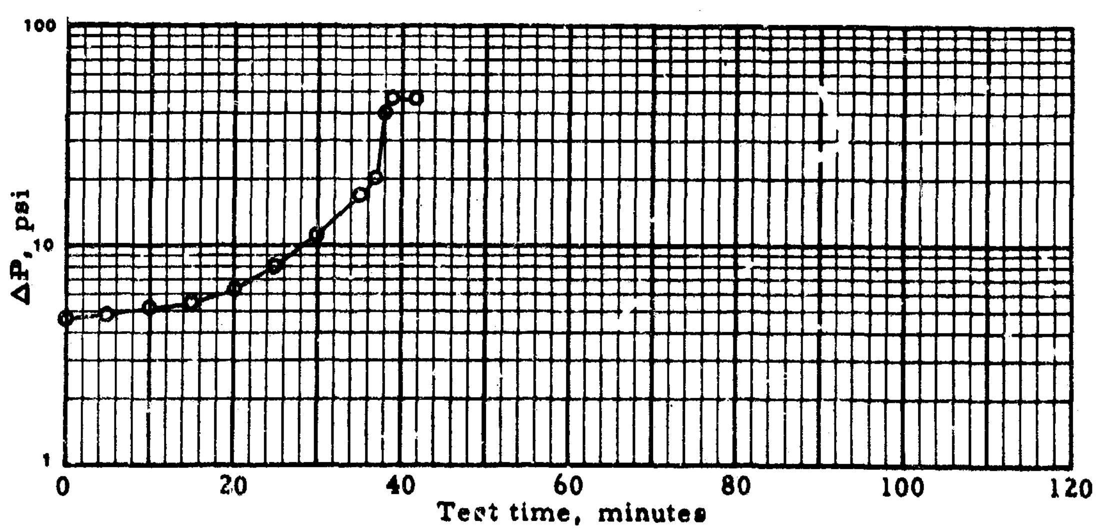


TABLE 177. SINGLE-ELEMENT LOOP TEST NO. 313

Date: 26 June 1969

Loop no.	3(Al/SS)	Housing:	8" I D Aluminum
		Element:	Filters Inc[a]
		Canister:	DoD Type 1

Procedure no.	13-A	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Coarse AC Dust	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated

Date blended with additives: 25 June 1969

Anti-icing additive 0.15 vol %, Dow, Lot 02268 16

Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	40	Calculated dirt loading, g	229
Fuel throughput, gal	810	Actual element weight gain, g	230
Average rate, gpm	20.2		

Time	0 min	End Test
Meter reading, gal	300	1110
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-test	Post-test
WSIM, distilled water	96	68	73
IFT, distilled water, dyn/cm	32.0	23.4	24.5

Analyses on injection water:

Time	Post-test
Solids, mg/liter	0.1
pH	7.8
ST, dyn/cm	72.0

a. Government standard elements, DSA 700 68-C-B526, Filters Inc. part No. I-4208, manufactured 10-68.

TABLE 177. SINGLE-ELEMENT LOOP TEST NO. 313 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.9	0	0			80
5	5.5	0	0	0.22	8- 9	80
10	5.5	0	0			80
15	5.5	0	0			80
20	6.3	0	0			80
25	7.3	0	0			80
30	9.0	0	0			80
35	12.5	0	0			80
40	20.0	0	0	0.91	18-19	80
40.5	40.0	0	3	0.85	20++	80
41	50+	0	7			80
44	--	0	1			80

Schedule:

Minutes	Water, gpm	Solids, g/min
C-40	0.002	5.72
40-40.5	0.2	---

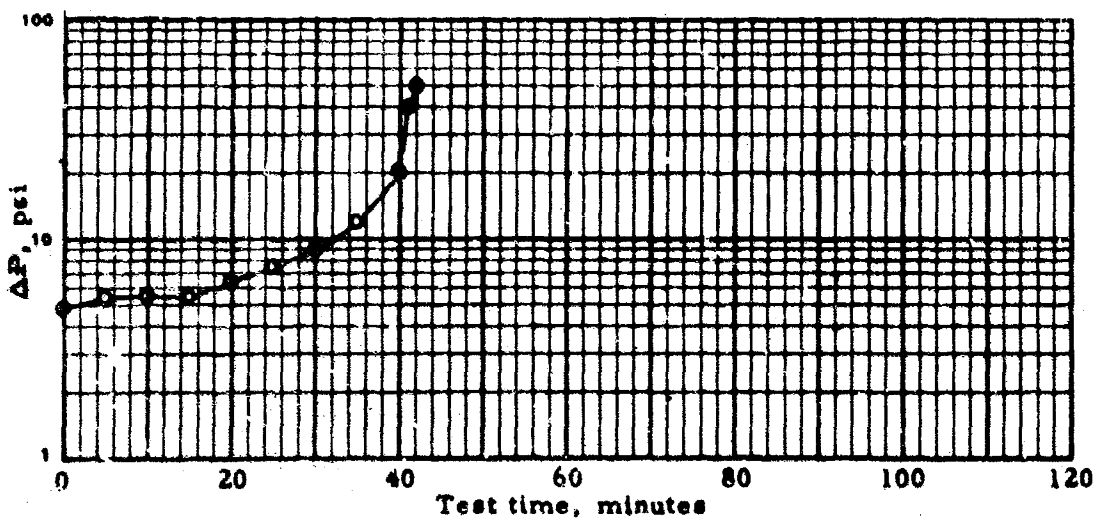


TABLE 176. SINGLE-ELEMENT LOOP TEST NO. 314 Date: 1 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Bendix[a], No. 69M 2814
		Canister:	DoD type 1

Procedure no. 8901-B (Modified)		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Red Iron Oxide (R-9998)		Fuel inlet pressure, psi	70

Water injection schedule: 0.2 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min from 60 min to end of test.

Test fuel JP-5 batch no. 25 , fresh, clay treated
Date blended with additives: 30 June 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 10 lb/Mbbl, AFA-1 , Lot 199

Test duration, min	130	Calculated dirt loading, g	200
Fuel throughput, gal	2600	Actual element weight gain, g	108
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	298	2898
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	82	90
IFT, distilled water, dyn/cm	44.5	25.1	25.9

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.4
ST, dyn/cm	71.4

a. Special element for red iron oxide.

TABLE 178. SINGLE-ELEMENT LOOP TEST NO. 314 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.0	0	0			80
5	5.1	0	1			80
10	5.5	0	0			80
15	5.5	0	1		16-17	80
20	5.5	0	1		16-17	80
25	5.6	0	2			80
30	5.6	0	2		16-17	80
35	5.8	0	2			80
40	5.9	0	2			80
45	5.9	0	2		17-18	80
50	5.9	0	2			80
55	5.9	0	2			80
60	5.9	0	2		17-18	80
65	6.0	0	10	1.08	17-18	80
70	6.0	0	26	2.96		80
75	6.1	0	29			80
80	6.4	0	34	5.87	17-18	80
85	6.5	0	40			80
90	6.7	0	44	10.97	17-18	80
95	7.0	0	48			80
100	8.0	0	51	15.26	18-19	80
105	8.0	-	57			80
110	8.4	0	50	14.13	18-19	80
115	8.0	0	50			80
120	8.0	0	50	13.24	18-19	80
125	8.0	0	50			80
130	8.5	0	53	16.76	18-19	80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-60	0.2	--
	60-130	0.2	2.86

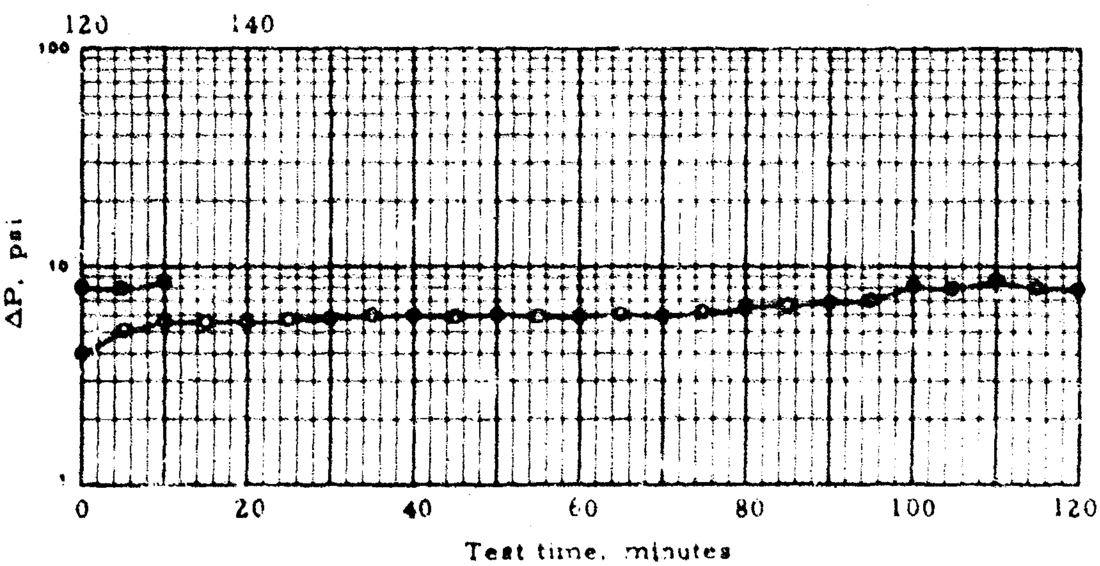


TABLE 179. SINGLE-ELEMENT LOOP TEST NO. 315 Date: 2 July 69

Loop no. 3(Al/SS)		Housing:	3" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Ground Iron Ore	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 1 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, AFA-1, Lot 199

Test duration, min	55	Calculated dirt loading, g	297
Fuel throughput, gal	a	Actual element weight gain, g	289
Average rate, gpm	a		

Time	0 min	End Test
Meter reading, gal	300	a
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	79	90
IFT, distilled water, dyn/cm	46.8	21.8	21.3

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.5
ST, dyn/cm	71.4

a. Brodie meter became inoperable during last part of test.

TABLE 179. SINGLE-ELEMENT LOOP TEST NO. 315 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.0	0	2			80
2	4.1	0	6	0.69	0-1	80
5	4.4	0	5		2-3	80
10	4.6	0	5			80
15	5.0	0	2		4-5	80
20	5.1	0	2			80
25	5.4	0	2			80
30	5.9	0	2			80
35	6.5	0	2	0.44	8-9	80
40	7.8	0	2		5-6	80
45	10.4	0	3			80
50	17.5	0	3			80
52	20.0	0	3	0.91	7-8	80
55	40.0	0	8	0.91	18-19	80
60	39.0	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-52	0.002	5.72
	52-55	0.2	--

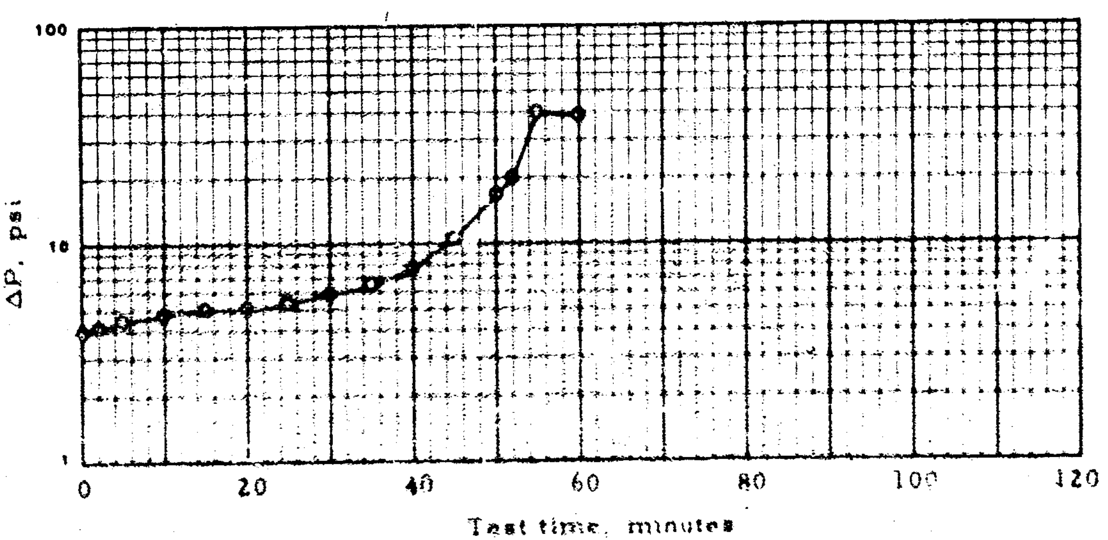


TABLE 180. SINGLE-ELEMENT LOOP TEST NO. 316 Date: 3 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P		Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Ground Iron Ore	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated

Date blended with additives: 2 July 69

Anti-icing additive 0.15 vol %, Dow, Lot 0226816

Corrosion inhibitor 16 lb/Mbbl, AFA-1, Lot 199

Test duration, min	56	Calculated dirt loading, g	309
Fuel throughput, gal	1118	Actual element weight gain, g	306
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	395	1513
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	96	84	86
IFT, distilled water, dyn/cm	45.4	21.2	21.0

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	7.7
ST, dyn/cm	71.0

TABLE 180. SINGLE-ELEMENT LOOP TEST NO. 316 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.7	0	0			80
5	5.5	0	3	0.40	5-10	80
10	5.3	0	1		5-10	80
15	5.3	0	1			80
20	5.5	0	1			80
25	5.7	0	1			80
30	6.1	0	1			80
35	6.6	0	1			80
40	7.5	0	1			80
45	9.2	0	1			80
50	12.8	0	1			80
54	20.0	0	2	0.57	15-16	80
56	40.0	0	8	0.41	20	80
58	46.6	0	6			80
59	42.3	0	2			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-54	0.002	5.72
	54-56	0.2	--

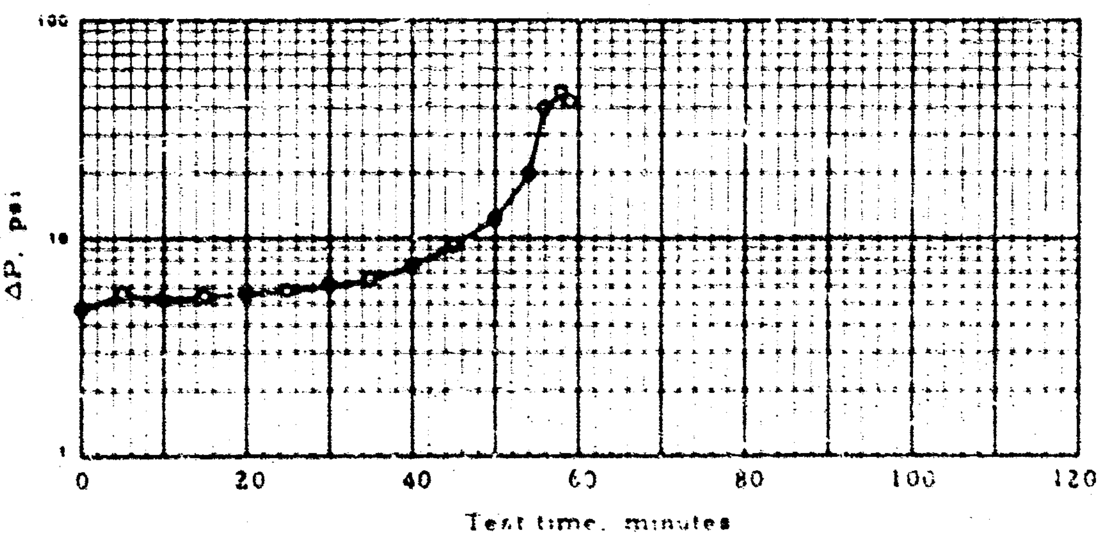


TABLE 181. SINGLE-ELEMENT LOOP TEST NO. 317 Date: 8 July 69

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Ground Iron Ore		Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 7 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH 04-006

Test duration, min	72	Calculated dirt loading, g	
Fuel throughput, gal	1433	Actual element weight gain, g	
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	300	1733
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	78	93
IFT, distilled water, dyn/cm	45.8	28.9	35.4

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.8
ST, dyn/cm	66.4

TABLE 181. SINGLE-ELEMENT LOOP TEST NO. 317 (Cont'd)

Time, min	ΔP, psi	Totamitor		Effluent, mg/liter		Influent fuel temperature, °F
		Infl	Effl	Solids	Free water	
0	4.0	0	0			80
5	4.5	0	0	0.10	2-3	80
10	4.5	0	0			80
15	4.7	0	0			80
20	4.9	0	0			80
25	5.4	0	0			80
30	6.0	0	0			80
35	6.8	0	0			80
40	8.0	0	0			80
45	9.9	0	0			80
50	12.8	0	0			80
55	18.2	0	0			80
56	20.0	0	0	0.15	6-7	80
61	33.0	0	1	0.06	8-9	80
66	36.5	0	1		17-18	80
71	38.5	0	1		17-18	80
72	40.0	0	1	0.08	18-19	80
73	41.6	0	1			80
75	35.5	0	1			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-56	0.002	5.72
56-71	0.2	--
71-72	0.2	5.72

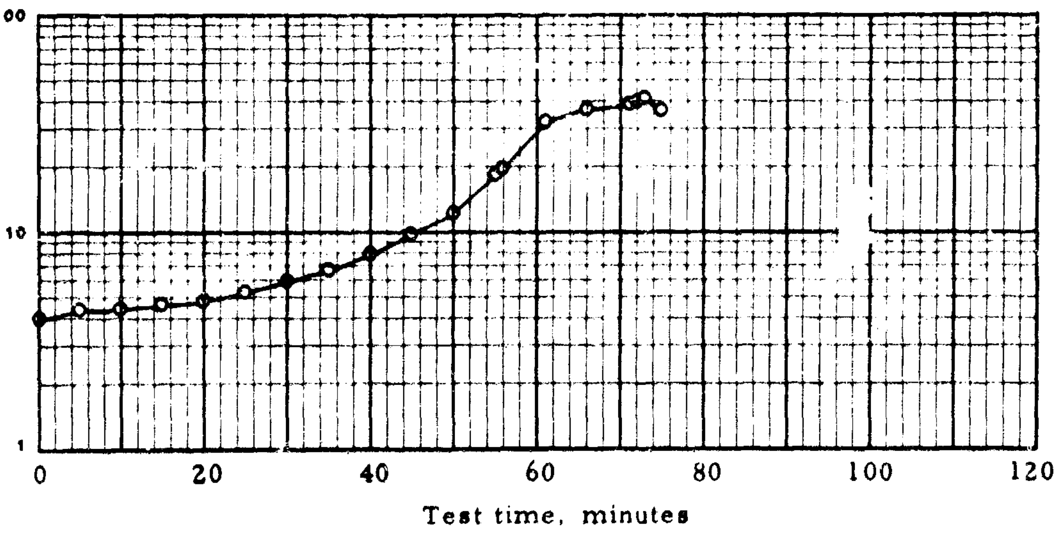


TABLE 182 . SINGLE-ELEMENT LOOP TEST NO. 318 Date: 9 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc. I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Ground Iron Ore		Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 24 , reused, clay treated
Date blended with additives: 8 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C , Lot NH 04-006

Test duration, min	76	Calculated dirt loading, g	383
Fuel throughput, gal	1520	Actual element weight gain, g	364
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	1820
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	95	96
IFT, distilled water, dyn/cm	40.3	35.7	35.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	Neg
pH	7.9
ST, dyn/cm	70.5

TABLE 182. SINGLE-ELEMENT LOOP TEST NO. 318 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.5	0	0			80
5	3.9	0	0	0.14	0	80
10	3.8	0	0			80
15	4.0	0	0			80
20	4.0	0	0			80
25	4.3	0	0			80
30	4.5	0	0			80
35	4.9	0	0			80
40	5.4	0	0			80
45	6.0	0	0			80
50	7.4	0	0			80
55	9.3	0	0			80
60	12.1	0	0			80
65	16.8	0	0			80
67	20.0	0	0	0.22	2-3	80
72	36.5	0	85	0.30	20+	80
76	40.0	0	100+	0.36	20++	80
77	40.0	C	100+			80
79	33.6	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-67	0.002	5.72
	67-76	0.2	--

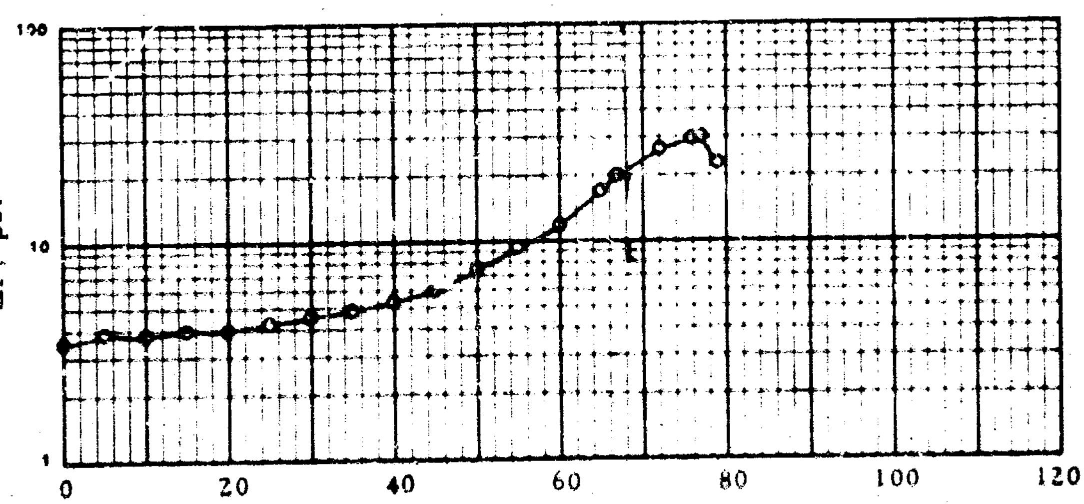


TABLE 183. SINGLE-ELEMENT LOOP TEST NO. 319 Date: 10 July 69

Loop no.3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no.	13-P	Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Ground Iron Ore	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25 , reused, clay treated
Date blended with additives: 9 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	125	Calculated dirt loading, g	635
Fuel throughput, gal	2550	Actual element weight gain, g	595
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	2805
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	98	93	98
IFT, distilled water, dyn/cm	39.4	43.5	42.3

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.7
ST, dyn/cm	70.6

TABLE 183. SINGLE-ELEMENT LOOP TEST NO. 319 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.8	0	0			80
5	3.9	0	0	0.15	0	80
10	4.0	0	0			80
15	4.1	0	0			80
20	4.2	0	0			80
25	4.3	0	0			80
30	4.4	0	0			80
35	4.5	0	0			80
40	4.6	0	0			80
45	4.9	0	0			80
50	5.2	0	0			80
55	5.5	0	0			80
60	5.8	0	0			80
65	6.3	0	0			80
70	7.3	0	0			80
75	8.3	0	0			80
80	9.8	0	0			80
85	11.5	0	0			80
90	13.6	0	0		0-1	80
95	16.1	0	0			80
101	20.0	0	0	0.07	2-3	80
106	16.5	0	0	0.02	1-2	80
111	15.5	0	0		2-3	80
116	16.2	0	0		0-1	80
120	25.5	0	0			80
126	40.0	0	0	0.06	0-1	80
127	40.6	0	0			80
129	38.0	0	0			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-101	0.002	5.72
101-116	0.2	--
116-125	0.2	5.72

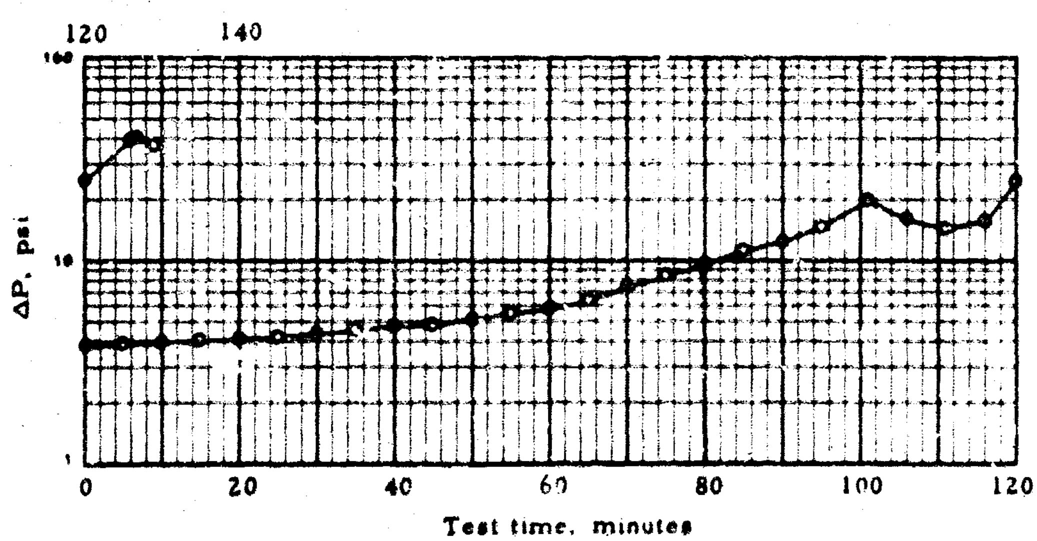


TABLE 184. SINGLE-ELEMENT LOOP TEST NO. 320 Date: 11 July 69

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Ground Iron Ore		Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 10 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH 04-006

Test duration, min	63	Calculated dirt loading, g	297
Fuel throughput, gal	1252	Actual element weight gain, g	286
Average rate, gpm	19.9		

Time	0 min	End Test
Meter reading, gal	298	1550
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	83	91
IFT, distilled water, dyn/cm	44.1	34.3	33.4

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.8
ST, dyn/cm	70.8

TABLE 184. SINGLE-ELEMENT LOOP TEST NO. 320 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.3	0	0			80
5	5.1	0	0	Neg	0	80
10	4.9	0	0			80
15	5.0	0	0			80
20	5.2	0	0			80
25	5.8	0	0			80
30	6.6	0	0			80
35	7.8	0	0			80
40	9.8	0	0			80
45	12.6	0	0		0-1	80
50	16.4	0	0			80
52	20.0	0	0	0.01	1-2	80
55	31.5	0	0			80
57	34.5	0	0	0.07	1-2	80
62	37.4	0	0			80
63	40.0	0	0	0.11	4-5	80
64	42.5	0	1			80
67	37.5	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-52	0.002	5.72
	52-63	0.2	--

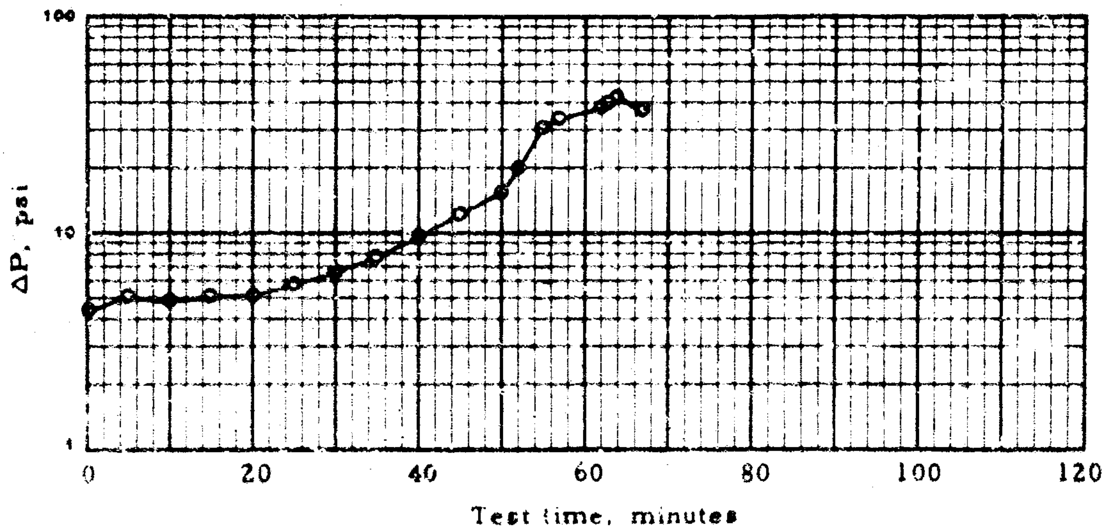


TABLE 185. SINGLE-ELEMENT LOOP TEST NO. 321 Date: 14 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P		Fuel flow, gpm	20
Water:	Filtered Tap Water	Fuel inlet temperature, °F	80
Solids:	Ground Iron O	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25 , reused, clay treated

Date blended with additives: 14 July 69

Anti-icing additive 0.15 vol %, Dow, Lot 0226816

Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	49	Calculated dirt loading, g	274
Fuel throughput, gal	981	Actual element weight gain, g	163
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	299	1280
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	62	52
IFT, distilled water, dyn/cm	41.5	25.1	25.6

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.2
pH	7.8
ST, dyn/cm	70.2

TABLE 185. SINGLE-ELEMENT LOOP TEST NO. 321 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.2	0	0			80
5	3.6	0	12	0.58	1-2	80
10	4.0	0	8		1-2	80
15	4.1	0	5			80
20	4.4	0	4			80
25	4.8	0	3			80
30	5.4	0	2			80
35	6.8	0	2			80
40	9.6	0	3			80
45	16.2	0	3			80
48	20.0	0	4	2.09	7-8	80
49	40.0	0	57	2.63	20+	80
50	43.0	0	57			80
53	38.4	0	2			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-48	0.002	5.72
48-49	0.2	--

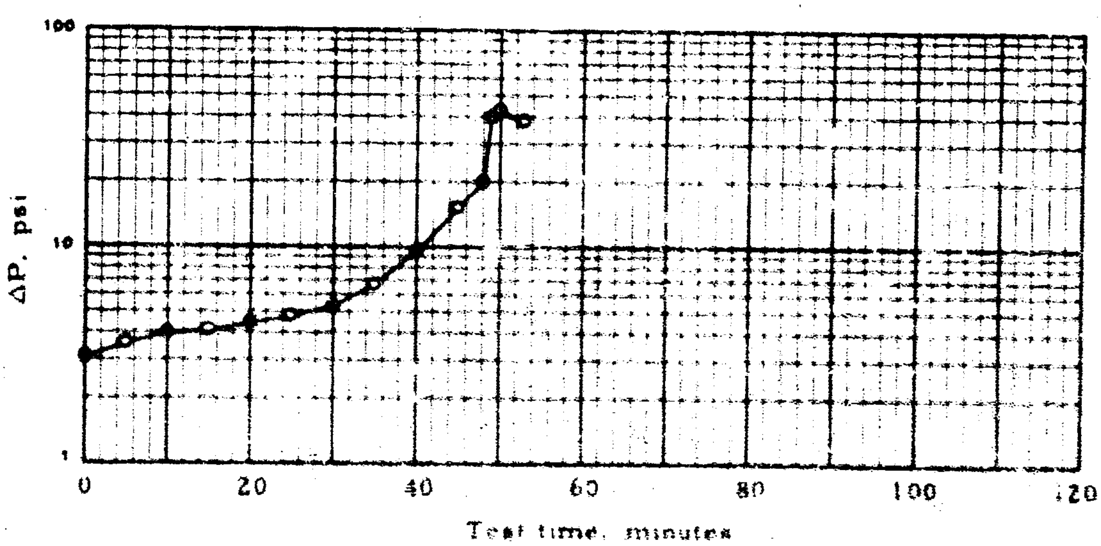


TABLE 186 . SINGLE-ELEMENT LOOP TEST NO. 322 Date: 15 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-P	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Ground Iron Ore	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25 , reused, clay treated
Date blended with additives: 14 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 20 lb/Mbbl, Lubrizol 541 , Lot 24794

Test duration, min	47	Calculated dirt loading, g	263
Fuel throughput, gal	945	Actual element weight gain, g	250
Average rate, gpm	20.1		

Time	0 min	End Test
Meter reading, gal	300	1245
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	95	59	85
IFT, distilled water, dyn/cm	43.4	26.5	26.7

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.1
pH	7.6
ST, dyn/cm	71.0

TABLE 186. SINGLE-ELEMENT LOOP TEST NO. 322 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.0	0	0			80
5	4.9	0	8	0.25	1-2	80
10	4.7	0	4			80
15	5.0	0	2			80
20	5.4	0	2			80
25	6.2	0	1			80
30	7.4	0	1			80
35	9.0	0	1			80
40	12.0	0	1			80
45	17.0	0	1			80
46	20.0	0	1	0.52	17-18	80
47	40.0	0	37	1.42	14-15	80
48	47.5	0	40			80
51	43.5	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-46	0.002	5.72
	46-47	0.2	--

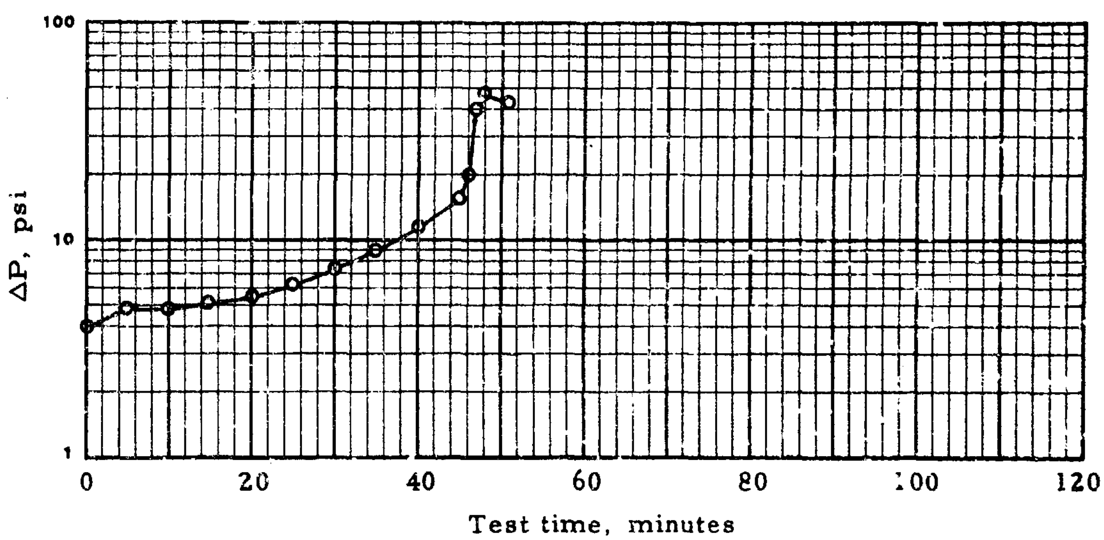


TABLE 187. SINGLE-ELEMENT LOOP TEST NO. 323 Date: 16 July 69

Loop no. 3(Al/SS)	Housing: 8" ID Aluminum
	Element: Filters Inc, I 4208 Lot 516
	Canister: DoD type 1

Procedure no. 13-Q		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Black Iron Oxide (Magnetic)		Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 15 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH 04-006

Test duration, min	67	Calculated dirt loading, g	360
Fuel throughput, gal	1348	Actual element weight gain, g	357
Average rate, gpm	20.1		

Time	0 min	End Test
Meter reading, gal	300	1648
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	99	85	94
IFT, distilled water, dyn/cm	44.1	37.0	38.9

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.2
pH	7.7
ST, dyn/cm	71.0

TABLE 187. SINGLE-ELEMENT LOOP TEST NO. 323 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	0	0			80
5	4.3	0	0	0.06	0	80
10	4.5	0	0			80
15	4.7	0	0			80
20	4.9	0	0			80
25	5.3	0	0			80
30	6.0	0	0		0-1	80
35	6.9	0	0			80
40	7.9	0	0			80
45	9.3	0	0			80
50	11.1	0	0			80
55	13.4	0	0			80
60	17.5	0	0			80
63	20.0	0	0	0.02	5-6	80
67	40.0	0	4	0.10	19-20	80
69	42.5	0	4			80
70	36.9	0	1			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-63	0.002	5.72
63-67	0.2	--

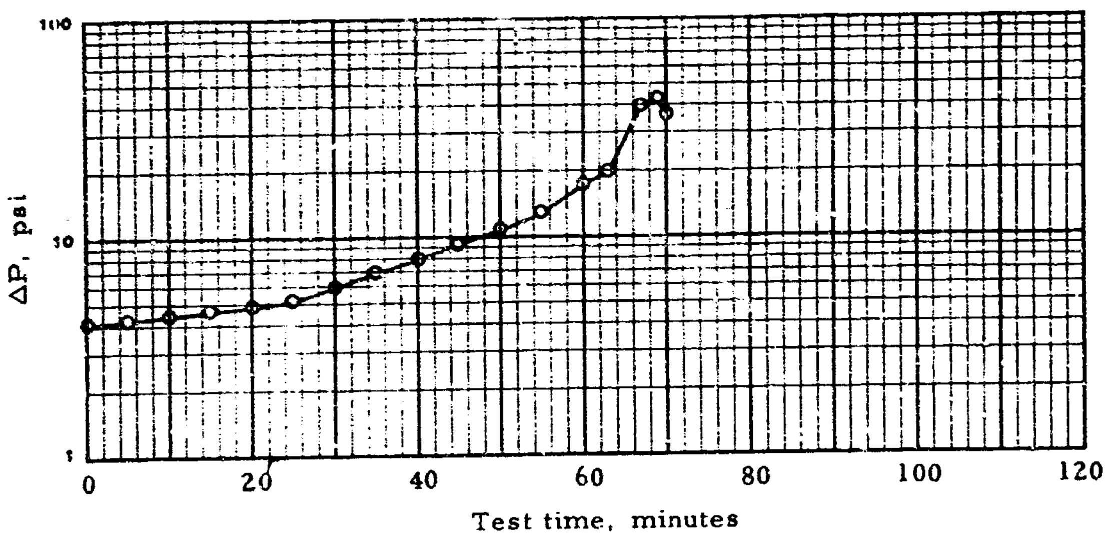


TABLE 188. SINGLE-ELEMENT LOOP TEST NO. 324 Date: 17 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Filters Inc, I 4208 Lot 516
		Canister:	DoD type 1

Procedure no. 13-Q	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Black Iron Oxide (Magnetic)	Fuel inlet pressure, psi	70

Water injection schedule: 0.002 gpm from 0 min to 20 psi, then 0.2 gpm to end of test.

Solids injection schedule: 5.72 g/min from 0 min to 20 psi, then discontinue 15 min, then 5.72 g/min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 16 July 69
Anti-icing additive 0.15 vol %, Dow, Lot C226816
Corrosion inhibitor 16 lb/Mbbl, Santolene C, Lot NH 04-006

Test duration, min	81	Calculated dirt loading, g	378
Fuel throughput, gal	1620	Actual element weight gain, g	391
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	1920
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	97	90	95
IFT, distilled water, dyn/cm	41.5	33.8	38.4

Analyses on injection water:

Time	Post-Test
Solids, mg/liter	0.0
pH	7.9
ST, dyn/cm	71.8

TABLE 188. SINGLE-ELEMENT LOOP TEST NO. 324 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.1	0	0			80
5	3.3	0	)	0.01	0-1	80
10	3.4	0	0			80
15	3.7	0	0			80
20	3.9	0	0			80
25	4.4	0	0			80
30	4.6	0	0			80
35	5.0	0	0			80
40	5.8	0	0			80
45	7.4	0	0			80
50	9.4	0	0			80
55	12.0	0	0			80
60	14.9	0	0			80
66	20.0	0	0	Neg	3-4	80
71	33.1	0	5	0.04	16-17	80
76	36.6	0	10		18-19	80
80	39.2	0	13		20+	80
81	40.0	0	15	0.16	20+	80
83	46.5	0	15			80
85	39.5	0	1			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-66	0.002	5.72
	66-81	0.2	--

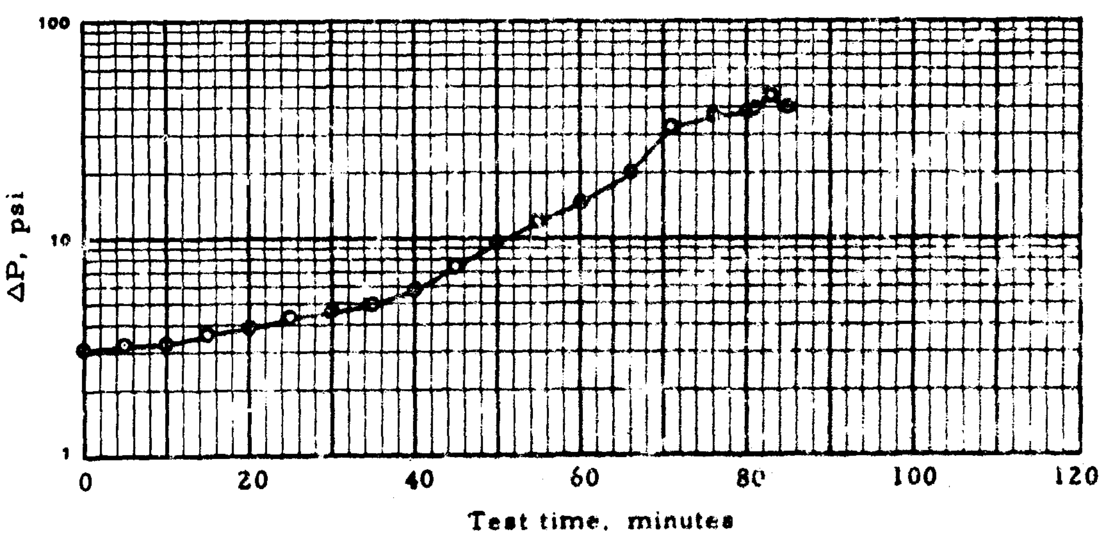


TABLE 189. SINGLE-ELEMENT LOOP TEST NO. 325 Date: 22 July 69

Loop no. 3(Al/SS)	Housing: 8" ID Aluminum
	Element: Bendix[a], No. 69 M 2814
	Canister: DoD type 1

Procedure no. 8901-B (Modified)	Fuel flow, gpm	20
Water: Filtered Tap Water	Fuel inlet temperature, °F	80
Solids: Red Iron Oxide R-9998	Fuel inlet pressure, psi	70

Water injection schedule: 0.2 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min from 60 min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 22 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 10 lb/Mbbl, AFA-1, Lot 199

Test duration, min	130	Calculated dirt loading, g	200
Fuel throughput, gal	2600	Actual element weight gain, g	134
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	2900
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post Test
WSIM, distilled water	99	72	95
IFT, distilled water, dyn/cm	47.7	24.5	25.8

Analyses on injection water:

Time	Pre-Test	Post-Test
Solids, mg/liter	--	0.0
pH	--	7.6
ST, dyn/cm	69.6	69.4

a. Special element for red iron oxide.

TABLE 189. SINGLE-ELEMENT LOOP TEST NO. 125 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.5	0	0		0	80
5	5.0	0	0		7-8	80
10	4.9	0	0		8-9	80
15	5.0	0	1		9-10	80
20	5.0	0	1			80
25	5.0	0	1			80
30	5.0	0	1		9-10	80
35	5.1	0	1			80
40	5.1	0	1			80
45	5.1	0	1		18-19	80
50	5.1	0	1		17-18	80
55	5.1	0	1		17-18	80
60	5.1	0	2		11-12	80
65	5.1	0	6	0.77	15-16	80
70	5.6	0	10	1.43	15-16	80
75	5.6	0	17			80
80	5.7	0	25	4.65	8-9	80
85	6.1	0	34			80
90	6.3	0	40	8.48	7-8	80
95	6.6	0	44			80
100	7.1	0	47	12.23	17-18	80
105	7.2	0	49			80
110	7.5	0	49	13.33	17-18	80
115	7.5	0	50			80
120	8.0	0	53	16.36	17-18	80
125	8.1	0	46			80
130	8.6	0	55	17.57	17-18	80
131	8.4	0	44			80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-60	0.2	--
60-131	0.2	2.86

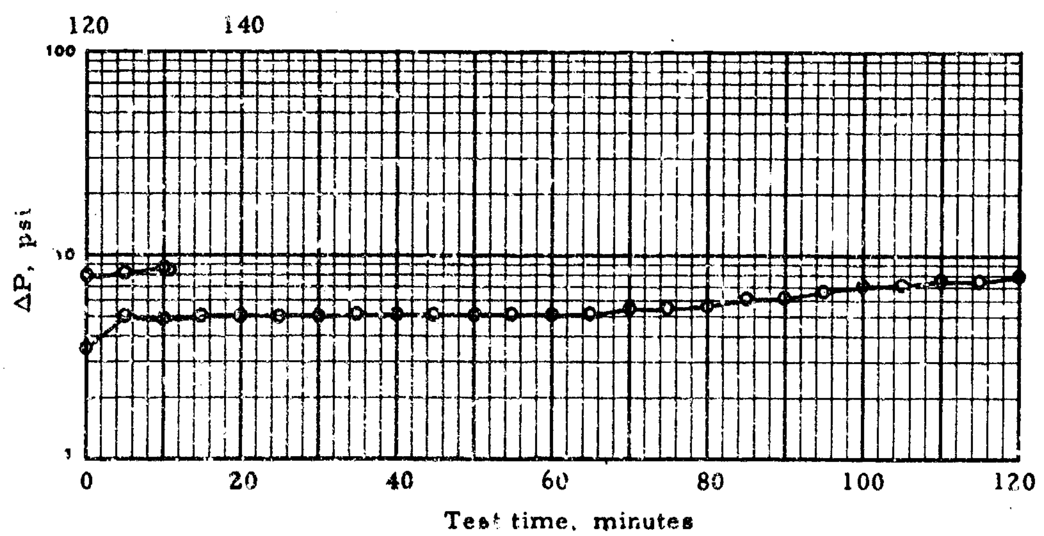


TABLE 190. SINGLE-ELEMENT LOOP TEST NO. 326 Date: 23 July 69

Loop no. 3(Al/SS)		Housing:	8" ID Aluminum
		Element:	Bendix[a], No. 69 M 2814
		Canister:	DoD type 1

Procedure no. 8901-B (Modified)		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Red Iron Oxide R-9998		Fuel inlet pressure, psi	70

Water injection schedule: 0.2 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min from 60 min to end of test.

Test fuel JP-5 batch no. 24, reused, clay treated
Date blended with additives: 22 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	130	Calculated dirt loading, g	200
Fuel throughput, gal	2600[b]	Actual element weight gain, g	227
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	312	2912
Screen ΔP, psi	2	2
Cleanup ΔP, psi	1	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	95	98
IFT, distilled water, dyn/cm	45.1	46.0	46.9

Analyses on injection water:

Time	Pre-Test	Post-Test
Solids, mg/liter	--	7.6
pH	--	0.3
ST, dyn/cm	71.8	71.7

a. Special element [illegible] iron oxide.
b. Brodie meter stopped 4 min into test. Flow rate maintained by holding Rotameter reading constant.

TABLE 190. SINGLE-ELEMENT LOOP TEST NO. 326 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	3.6	0	0		0	80
5	3.5	0	0		0-1	80
10	5.5	0	0			80
15	5.6	0	0		0-1	80
20	5.7	0	0			80
25	5.8	0	0			80
30	6.0	0	0		1-2	80
35	6.0	0	0			80
40	6.0	0	0			80
45	6.1	0	0		2-3	80
50	6.1	0	0			80
55	6.4	0	0			80
60	6.6	0	0		2-3	80
65	6.8	0	0	Neg	2-3	80
70	7.1	0	0	0.12	2-3	80
75	7.3	0	0			80
80	7.7	0	0	0.26	2-3	80
85	8.2	0	0			80
90	8.5	0	0	0.23	2-3	80
95	8.8	0	0			80
100	9.3	0	0	Neg	2-3	80
105	9.4	0	0			80
110	9.8	0	0	0.02	2-3	80
115	10.2	0	0			80
120	10.6	0	0	Neg	2-3	80
125	10.8	0	0			80
130	11.2	0	0	0.12		80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-60	0.2	--
60-131	0.2	2.86

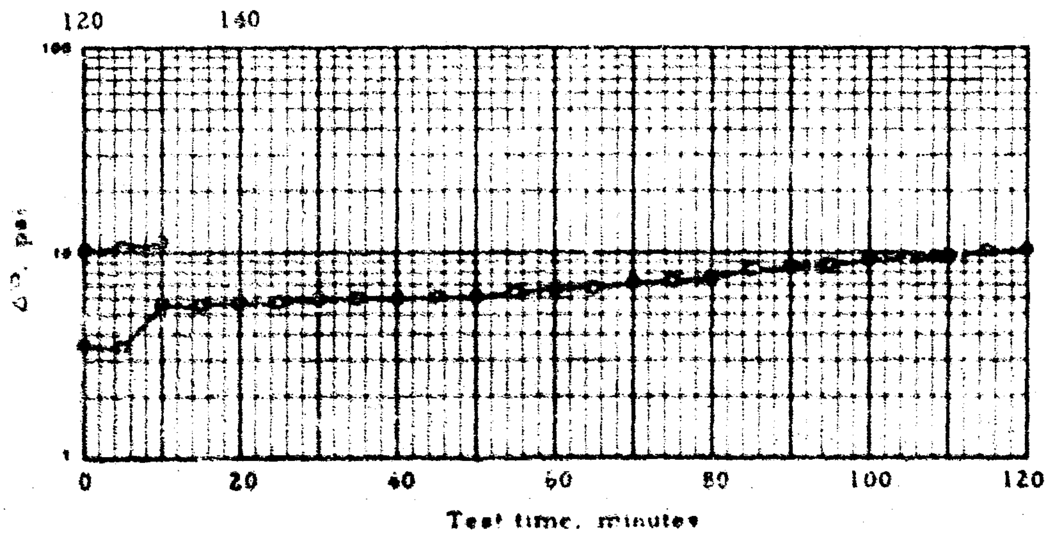


TABLE 191 . SINGLE-ELEMENT LOOP TEST NO. 327 Date: 25 July 69

Loop no. 3(Al/SS)		**Housing:**	8" ID Aluminum
		Element:	Bowser[a], No. A-1389-B
		Canister:	DoD type 1
Procedure no. 8901-B (Modified)		**Fuel flow, gpm**	20
Water: Filtered Tap Water		**Fuel inlet temperature, °F**	80
Solids: Red Iron Oxide R-9998		**Fuel inlet pressure, psi**	70

Water injection schedule: 0.2 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min from 0 min to end of test.

Test fuel JP-5 batch no. 25 , reused, clay treated
Date blended with additives: 24 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 10 lb/Mbbl, AFA-1 , Lot 199

Test duration, min	86	Calculated dirt loading, g	74
Fuel throughput, gal	1720	Actual element weight gain, g	62
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	2020
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	95	69	77
IFT, distilled water, dyn/cm	47.6	24.7	26.0

Analyses on injection water:

Time	Pre-Test	Post-Test
Solids, mg/liter	--	0.1
pH	--	--
ST, dyn/cm	70.8	65.4

a. Believed to be special element for red iron oxide.

TABLE 191. SINGLE-ELEMENT LOOP TEST NO. 327 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	4.1	0	0		0-1	80
5	6.5	0	1		19-20	80
10	6.7	0	1		20	80
15	7.0	0	2		20+	80
20	7.0	0	2			80
25	7.2	0	2			80
30	7.3	0	2		20	80
35	7.3	0	2			80
40	7.3	0	2			80
45	7.5	0	2		18	80
50	7.7	0	2			80
55	7.8	0	4			80
60	8.0	0	5		19-20	80
65	9.1	0	11	0.54	19-20	80
70	10.5	0	19	1.70	20+	80
75	13.0	0	30			80
80	17.5	0	56	2.44	20+	80
81	20.0	0	64	3.44	20+	80
85	36.6	0	100+	4.00	20+	[illegible]
86	40.0	0	100+	3.58	20+	80
87	47.2	0	100+			90
89	47.5	0	100+			80

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-60	0.2	--
	60-86	0.2	2.86

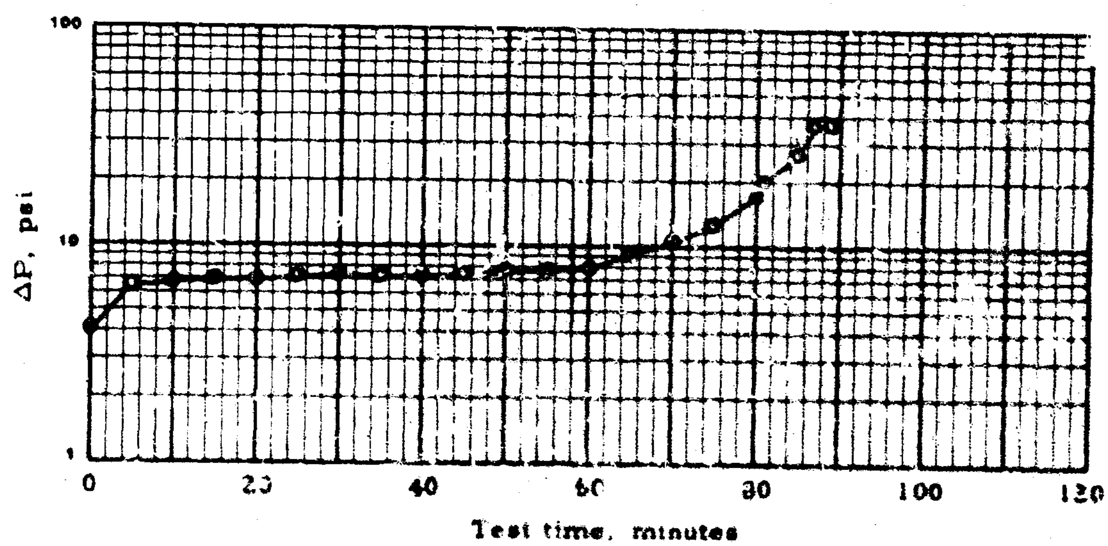


TABLE 192 . SINGLE-ELEMENT LOOP TEST NO. 328 Date: 28 July 69

Loop no. 3(Al/SS)		Housing: 8" ID Aluminum	
		Element: Bowser[a], No. A-1389-B	
		Canister: DoD type 1	
Procedure no.	8901-B (Modified)	Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Red Iron Oxide R-9998		Fuel inlet pressure, psi	70

Water injection schedule: 0.2 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min from 60 min to end of test.

Test fuel JP-5 batch no. 25, fresh, clay treated
Date blended with additives: None
Anti-icing additive None vol %, Dow, Lot
Corrosion inhibitor None lb/Mbbl, , Lot

Test duration, min	130	Calculated dirt loading, g	200
Fuel throughput, gal	2565	Actual element weight gain, g	178
Average rate, gpm	19.7		

Time	0 min	End Test
Meter reading, gal	300	2865
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	1

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	99	99	100
IFT, distilled water, dyn/cm	48.6	48.7	48.9

Analyses on injection water:

Time	Pre-Test	Post-Test
Solids, mg/liter	--	0.0
pH	--	7.5
ST, dyn/cm	72.4	72.4

a. Believed to be special element for red iron oxide.

TABLE 192. SINGLE-ELEMENT LOOP TEST NO. 328 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.0	0	0		0	80
5	7.3	0	0			80
10	7.3	0	0			80
15	7.3	0	0		2-3	80
20	7.3	0	0			80
25	7.3	0	0			80
30	7.3	0	0		2-3	80
35	7.3	0	0			80
40	7.3	0	0			80
45	7.3	0	0			80
50	7.3	0	0			80
55	7.5	0	0			80
60	7.5	0	0		2-3	80
65	7.6	0	0	0.11	7-8	80
70	8.0	0	0	0.11	2-3	80
75	8.0	0	0			80
80	8.2	0	0	Neg	3	80
85	8.2	0	0			80
90	8.5	0	0	0.25	3	80
95	8.6	0	0			80
100	12.9[a]	0	0	0.10	3	80
105	7.5	0	0			80
110	7.7	0	0	Neg	4	80
115	7.7	0	0			80
120	8.0	0	0	0.11	7	80
125	10.1	0	0			80
130	10.5	0	0	0.04	3	80
132	8.8	0	0			80

a. Flow rate 30 gpm.

Schedule:	Minutes	Water, gpm	Solids, g/min
	0-60	0.2	--
	60-132	0.2	2.86

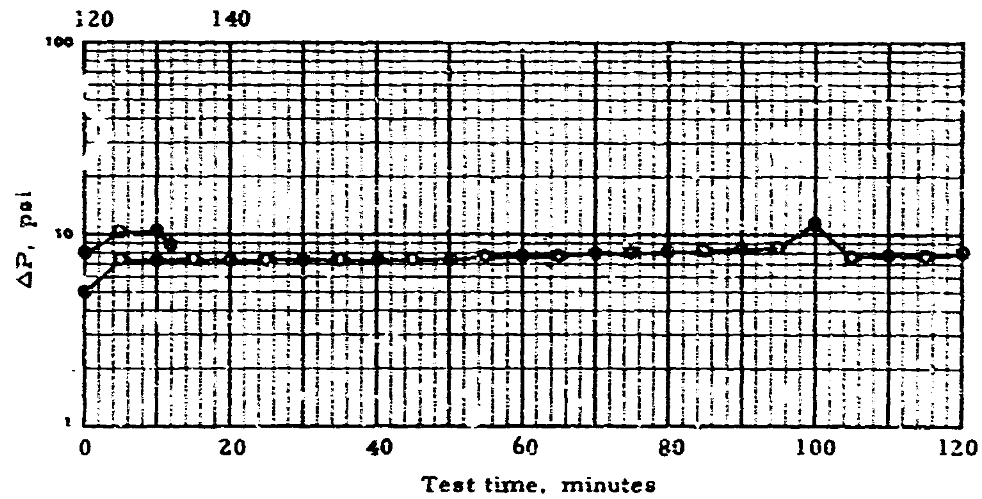


TABLE 193. SINGLE-ELEMENT LOOP TEST NO. 329 Date: 29 July 69

Loop no.	3(Al/SS)	Housing:	8" ID Aluminum
		Element:	Bowser[a], No. A-1389-B
		Canister:	DoD type 1

Procedure no. 8901-B		Fuel flow, gpm	20
Water: Filtered Tap Water		Fuel inlet temperature, °F	80
Solids: Red Iron Oxide R-9998		Fuel inlet pressure, psi	70

Water injection schedule: 0.2 gpm from 0 min to end of test.

Solids injection schedule: 2.86 g/min from 60 min to end of test.

Test fuel JP-5 batch no. 25, reused, clay treated
Date blended with additives: 28 July 69
Anti-icing additive 0.15 vol %, Dow, Lot 0226816
Corrosion inhibitor 10 lb/Mbbl, AFA-1 , Lot 199

Test duration, min	87	Calculated dirt loading, g	77
Fuel throughput, gal	1740	Actual element weight gain, g	68
Average rate, gpm	20.0		

Time	0 min	End Test
Meter reading, gal	300	2040
Screen ΔP, psi	2	2
Cleanup ΔP, psi	0	0

Analyses on influent fuel:

Time	Post Clay Filter	Pre-Test	Post-Test
WSIM, distilled water	100	64	76
IFT, distilled water, dyn/cm		24.7	25.1

Analyses on injection water:

Time	Pre-Test	Post-Test
Solids, mg/liter	--	Neg
pH	--	7.5
ST, dyn/cm	71.2	72.2

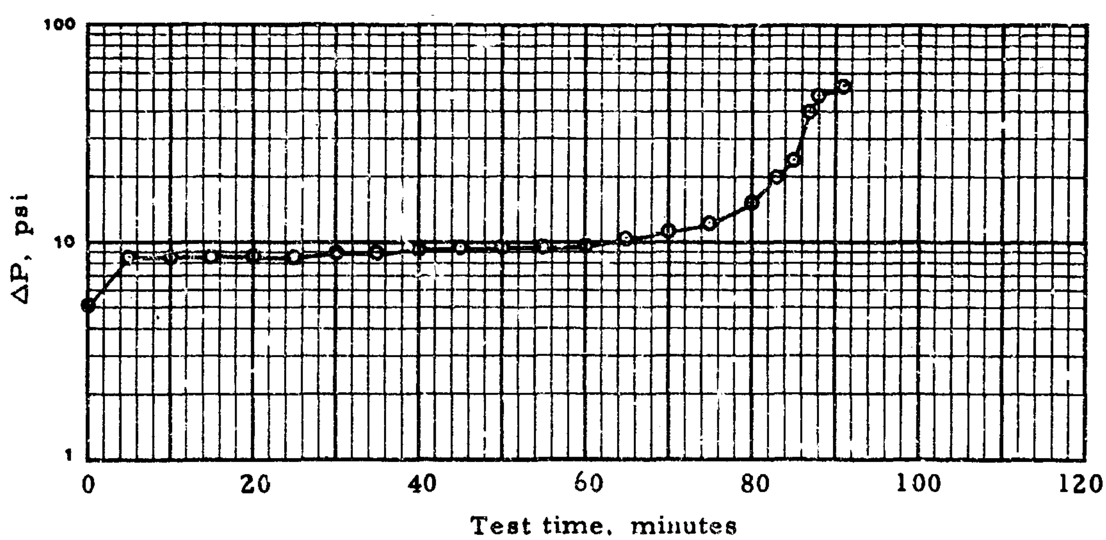
a. Believed to be special element for red iron oxide.

TABLE 193. SINGLE-ELEMENT LOOP TEST NO. 329 (Cont'd)

Time, min	ΔP, psi	Totamitor Infl	Totamitor Effl	Effluent, mg/liter Solids	Effluent, mg/liter Free water	Influent fuel temperature, °F
0	5.1	0	0		7-8	80
5	8.6	0	1		18-19	80
10	8.6	0	2		19-20	80
15	8.7	0	2		18-19	80
20	8.7	0	2			80
25	8.7	0	2			80
30	9.0	0	2		17-18	60
35	9.0	0	2			80
40	9.4	0	2			80
45	9.5	0	2		17-18	80
50	9.5	0	2			80
55	9.5	0	2			80
60	9.9	0	3		17-18	80
65	10.4	0	8	0.37	20+	80
70	11.5	0	12	0.52	20+	80
75	13.3	0	17			30
80	16.0	0	25	1.07	20+	80
83	20.0	0	28	1.71	20+	80
85	24.0	0	35			80
87	40.0	0	72	2.46	20+	80
88	47.5	0	22			80
91	50+	0				80

Schedule:

Minutes	Water, gpm	Solids, g/min
0-60	0.2	--
60-87	0.2	2.86



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	Air Force Aero Propulsion Laboratory Air Force Systems Command Wright-Patterson AFB, Ohio

13. ABSTRACT

Results are presented from the final year of a 5-year program in research and development in hydrocarbon fuel handling and contaminant control, along with a statistical analysis of results from earlier tests performed to develop procedures for evaluating filter-separator elements, fuels, and fuel additives. The program included a large number of tests in a single-element filter-separator test loop and a variety of small-scale studies. A small coalescer device was developed and operated to study the role of filter-media parameters in removal of free water from fuel. In the water separometer (WSIM) test, variability in coalescer disks was shown to be one of the primary sources of poor repeatability; no significant improvement could be made by the use of controlled washing or disk-conditioning procedures, but the use of fine media offered some promise for improvement. In a small-scale investigation of low-temperature plugging of filter media, it was found that addition of fuel system icing inhibitor (FSII) increased the plugging rates, and that elimination of the glycerol component of the FSII did not solve the problem completely. In an investigation of analytical methods for the FSII content of fuels, it was found that the standard refractometer method (Method 5340 in Fed Std 791a) gives results about 10% below the true values and that this systematic error can be eliminated by using a different method of calibration. Large-scale tests on a Static Charge Reducer demonstrated its effectiveness on several fuel blends at 300- and 600-gpm flow rates. The antistatic additive ASA-3 was effective in minimizing charge buildup in uninhibited JP-5 fuel but was less effective in these tests when the fuel contained a corrosion inhibitor.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Filtration						